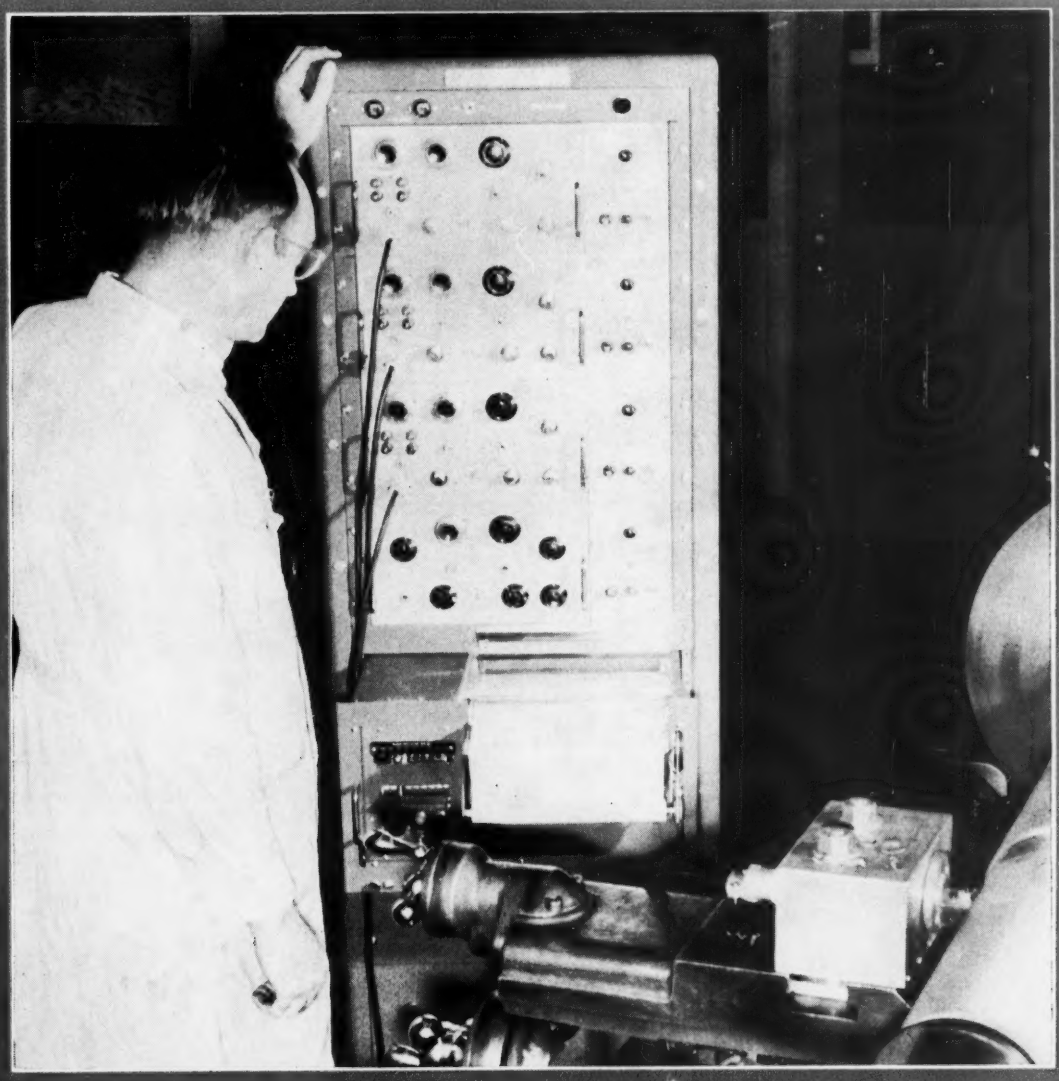
Vol. 13, No. 10 October, 1957

LUBRICATION ENGINEERING

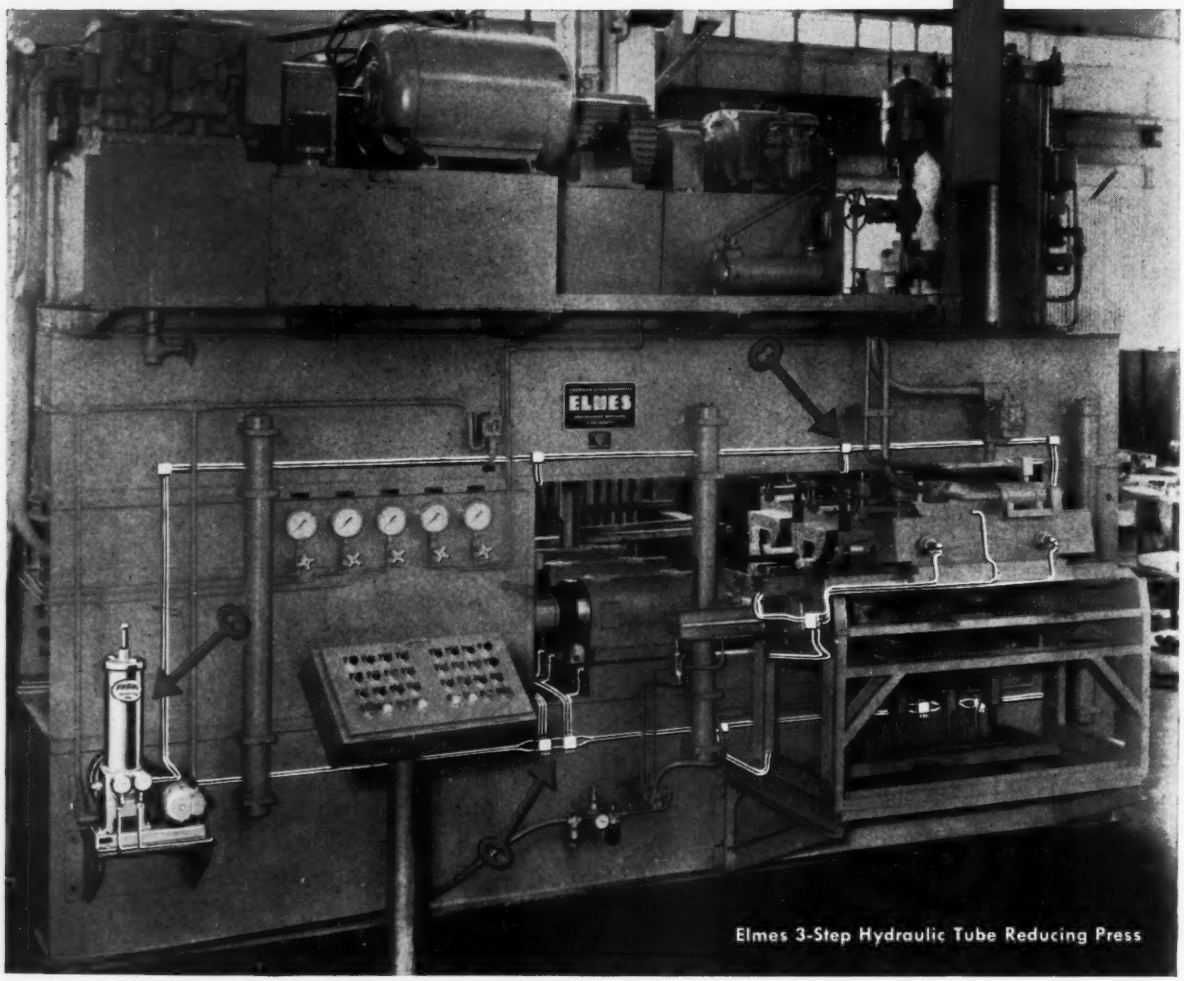
RESEARCH APPLICATION EDUCATION MAINTENANCE



JOURNAL OF THE AMERICAN SOCIETY OF LUBRICATION ENGINEERS

Never a holdup or slowdown to lubricate this tube reducer in Michigan auto factory

FARVAL—
Studies in Centralized Lubrication
No. 203



Elmes 3-Step Hydraulic Tube Reducing Press

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A Farval Centralized Lubrication System, manual or automatic, is easily designed into any machine. Let us send a representative to discuss application of Farval to your equipment. Drop us a line. Also ask for Bulletin 26-S. The Farval Corporation, 3267 East 80th Street, Cleveland 4, Ohio.

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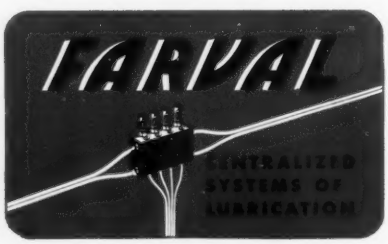
In Canada: Peacock Brothers Limited.

KEYS TO ADEQUATE LUBRICATION—

Wherever you see the sign of Farval—the familiar central pumping station, dual lubricant lines and valve manifolds—you know a machine is being properly lubricated.

This *Farvalized* machine is an Elmes 60-ton Tube Reducer. In three steps it reduces tubing for drive shafts for a well-known Michigan-made automobile.



LUBRICATION ENGINEERING

RESEARCH APPLICATION EDUCATION MAINTENANCE

Volume 13, No. 10

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COVER PICTURE: Three components of force on a cutting tool—under test on a lathe—are being measured here by this 4-channel electronic oscillograph under observation in the machinability laboratory of General Electric's Metallurgical Products Dept., Detroit. (Photo courtesy of General Electric Co.)

Abstracted by Engineering Index

LUBRICATION ENGINEERING is published monthly by the American Society of Lubrication Engineers, 84 E. Randolph St., Chicago 1, Illinois. Current volume single copies 75c. Copies of issues from previous volumes $1.00, if available; Copies to Foreign addresses add 50c per copy. Annual Subscription $6.00 in the USA and Canada, $7.00 to all other countries.

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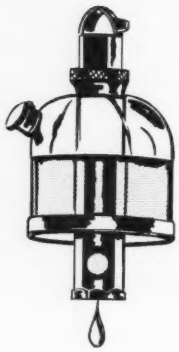


Highlights of Articles Scheduled for Coming Issues!

A Solution for the Finite Journal Bearing and Its Application to Analysis and Design — I

First results of a comprehensive program to facilitate the analysis and design of journal bearings is reported. Charts and tables are included which eliminate the need for side flow or leakage factors. The results are based upon data obtained by computer techniques in solving the fundamental equations for the journal bearing having a finite length-to-diameter ratio.

Temperature Effects in Journal Bearing Lubrication

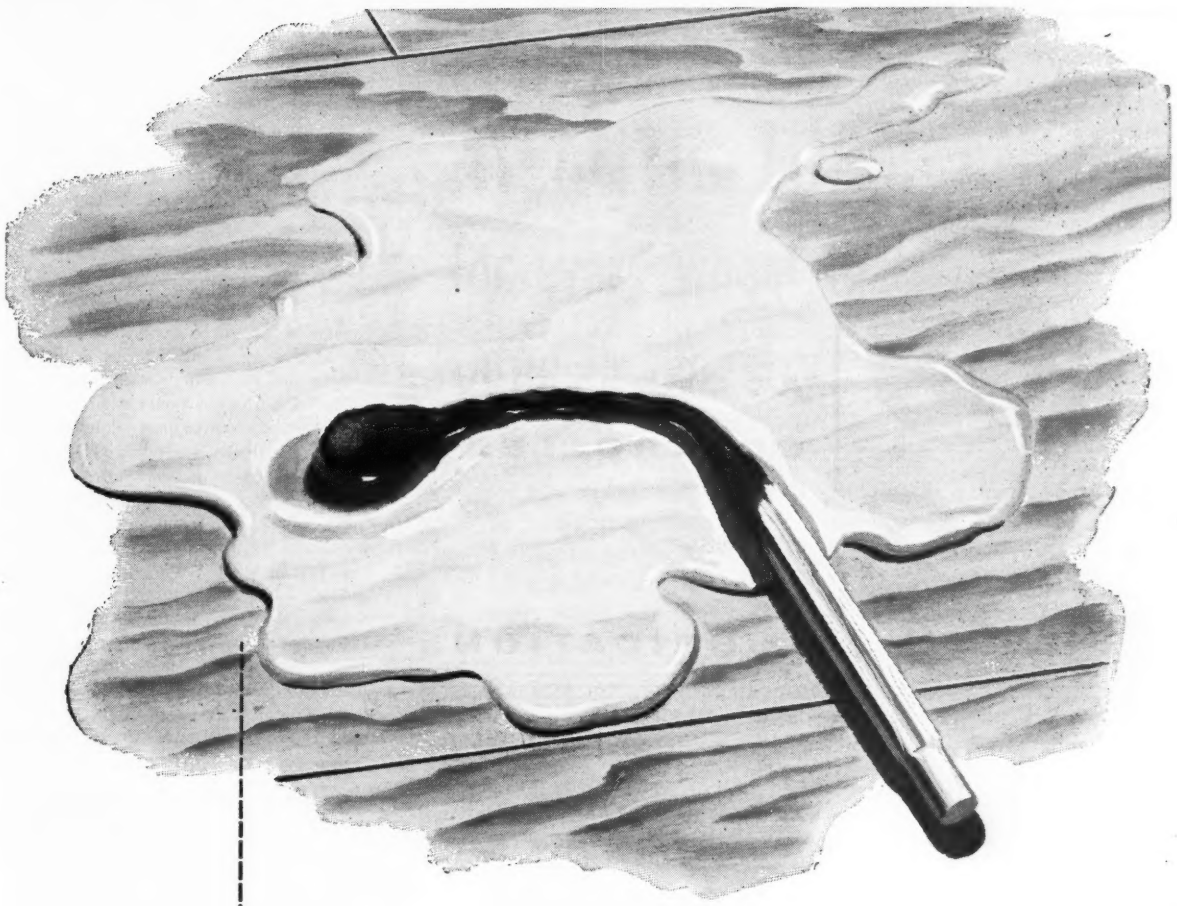
Temperature of the lubricant in service is known to rise as a result of the adsorption of a part of the heat generated by viscous friction. This temperature rise can reduce the lubricant's viscosity to such an extent that the pressure distribution in the lubricant film differs appreciably from that predicted when this relationship is solved using techniques which assume isothermal lubricant flow. The technique described assumes that lubricant flow is adiabatic, and side flow is neglected. Lubricant viscosity is taken to be a function of both pressure and temperature. Numerical solutions as examples are supplied using digital techniques.

A Lubrication Engineer Surveys Steel Mill Gearing—Part I.

In spite of the progress made in developing new lubricants for heavy duty operation of gears, serious problems of gear failure and overloading are encountered in the steel industry. Differences among criteria for the design of gears for steel mills has been partly responsible for gear failure — incomplete information on failure incidence and causes must also be blamed.

Steel Mill Gearing—Part II.

Predictions of wear and dynamic loading from formulas developed in part one of this paper are applied to actual gearing situations to determine what correlation exists as a basis for decreased gear failure.



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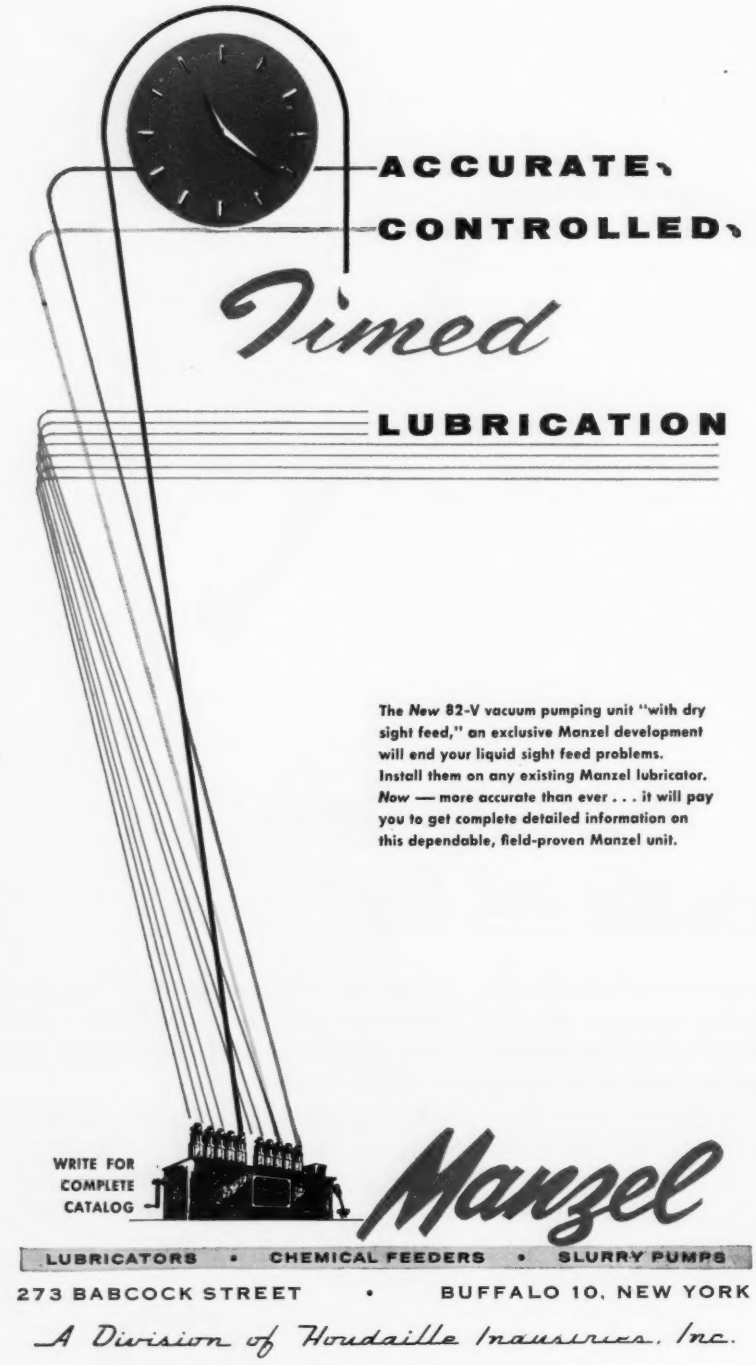
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PERSONALS . . .

EDWARD J. ROST is now lubrication engineer on the sales force of The Franklin Oil & Gas Co. of Bedford, Ohio. An active ASLE member, currently completing his term as Cleveland chapter chairman, Rost will call on concerns in the Northeastern Ohio area.

Werner G. Smith, Inc., Cleveland, Ohio, announced that E. W. Kaufmann will handle sales of sperm oil and chemical products in the Philadelphia area.

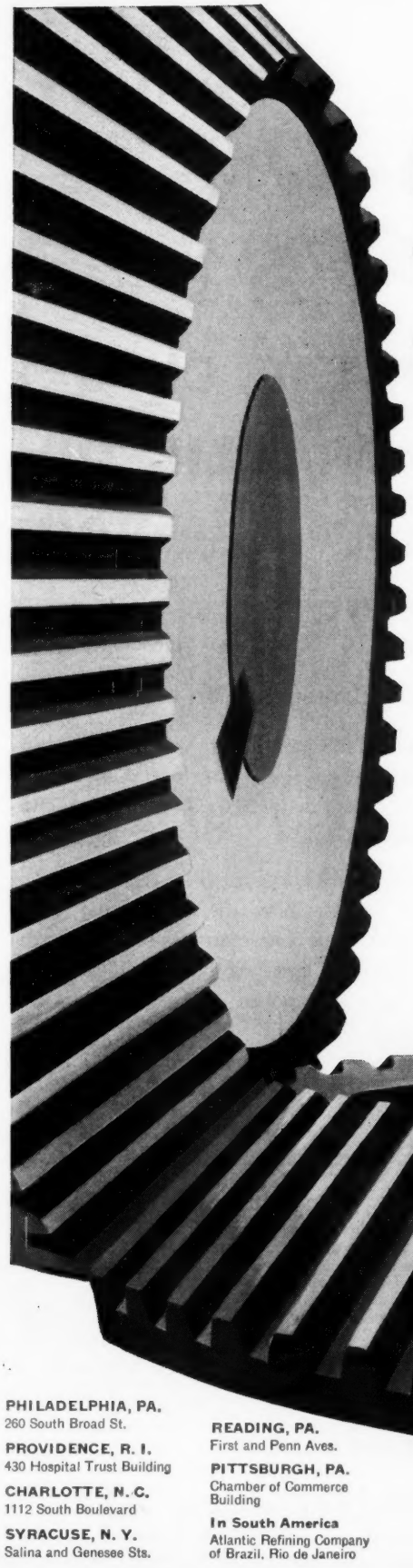
The Aro Equipment Corporation of Bryan, Ohio, manufacturers of lubricating equipment, aircraft products, and industrial air tools, has promoted E. C. Messervey to Chicago branch manager and Northern Illinois division manager of the Arolube Division. He will operate the Chicago branch sales office and service department and will be in charge of sales in Chicago, Northern Illinois and Lake County, Ind. James H. Thurow has been appointed Aro's division manager in Minneapolis, responsible for distributor sales of Arolube Equipment in Minnesota, North Dakota, South Dakota and eleven counties of Western Wisconsin.

William J. Lauter has been appointed product manager for the hydraulic-pneumatic line of products of The Garlock Packing Company, Palmyra, New York. He will supervise the marketing of Garlock's packing, cups, hat packing, O-rings and other related products.

Reuben Gutoff has been appointed manager of resin and fluids operations in the manufacturing section of the Silicone Products Department, General Electric Co., Waterford, N. Y. In his new position he will be responsible for the production of silicone resins, fluids, emulsions, and specialty products.

Formation of a new division of Jefferson Chemical Company's marketing department was announced today by Donald L. Griswold, general manager of the department. The move combines the market research division and the sales research and development division into a new group to be called the commercial development division. John J. Glover has been appointed manager and will assume his new duties on August 15. All functions of product development and market research will be handled by the commercial development division including product diversification and development of new sales.

Ian K. MacGregor has joined the Climax Molybdenum Company as vice president of eastern operations. Mr. MacGregor had been general manager of Manning, Maxwell and Moore, Inc. of Stratford, Connecticut, manufacturers of valves and instruments, since 1952.



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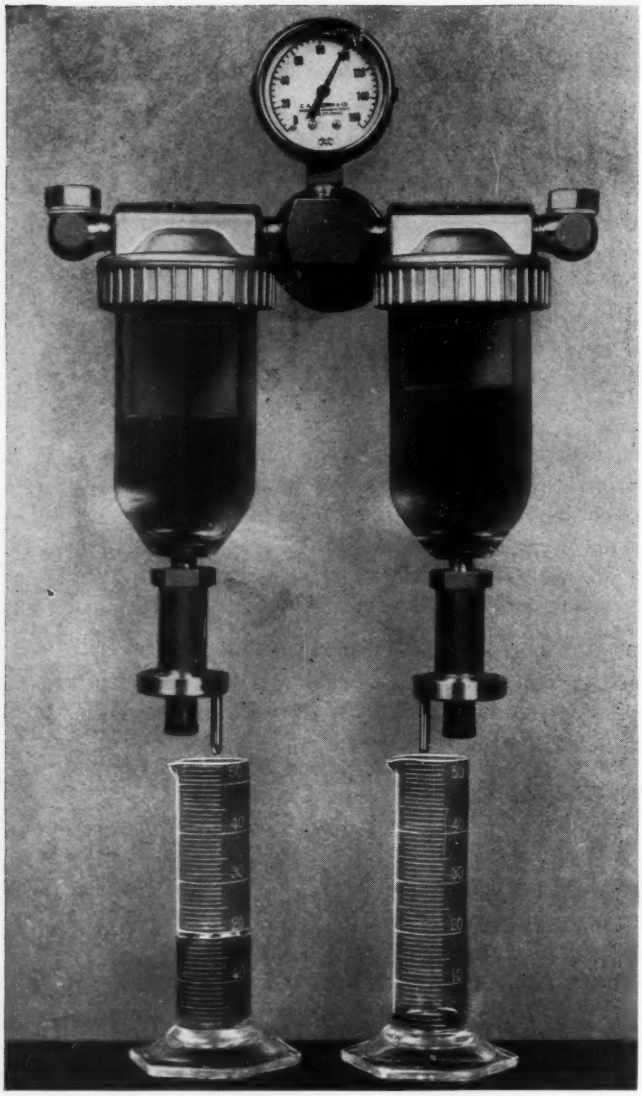

ANTILEAK DEMONSTRATION

Suntac oil in one chamber, your present hydraulic oil of the same viscosity in the other. Both oils are forced out through sintered bronze bearings. In this photograph, pressure of 100 psi caused a straight mineral oil to leak out four times faster than Suntac.

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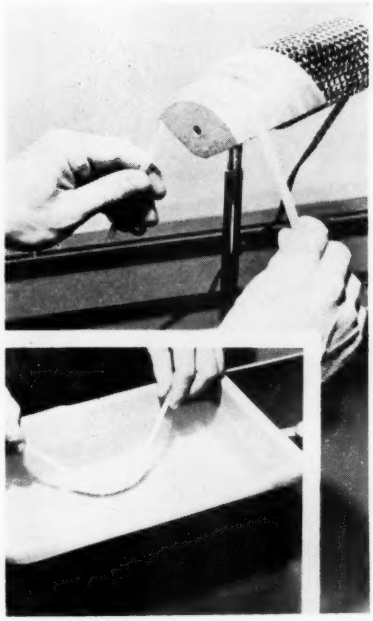
New Products

BENDER FOR POLYAMIDE TUBES

A tube known as a "Permabender" is now available for heat forming permanent bends in Nylaflow polyamide pressure tubing where preformed symmetrical lines are required in instrumentation and other fields. The 15 in. high tool has a heating element and mandrel with grooves to accommodate tubing sizes up to ⅜ in. O.D. The tubing is held in the heated groove for 10-20 seconds, then bent to desired radius and angle and cooled by immersion in water at room temperature for 10-15 seconds. Further information is available from The Polymer Corp. of Pennsylvania, Reading, Pa.



INSTRUMENT MEASURES DIFFERENTIAL PRESSURES

A new differential pressure indicator, measuring fast and slow transient differential pressures at any two points in a pneumatic or hydraulic system, also indicates short term measurements of the difference or sum of steady pressures at any two points. Momentary grounding of the input signal, to remove all the electrical charge generated by the steady component of pressure, makes possible measurement of a 0.1 psi change in differential pressure at a 3000 psi level. The same pickup is used for all pressure ranges to 3000 psi, with high pressure adaptors extending this range to 100,000 psi. Frequency range of the pickup is 0 to 50,000 cps, with capacity for continuous operation at 600° F. Because the sensing element is extremely rigid, the inertia of a column of liquid in front of the pickup has little effect on its response. For further on the Kistler SLM differential pressure indicator (Model DPI-114), write: Kistler Instrument Corp., 15 Webster St., North Tonawanda, N. Y.

SILICONE RUBBER MARKETED

A silicone rubber strong enough to replace organic rubber in many applications has been added to the standard product line of the Silicone Products Dept., General Electric Co., Waterford, N. Y. Designated SE-555, this compound is now available in commercial quantities. Possessing unusual physical strength, low moisture absorption and good oil resistance, the material is especially suited for aircraft seals and gaskets for use in the —150 to 500 F. range. Typical physical properties include 1,600 psi tensile strength, 650 to 850 per cent elongation, and 200 to 250 lbs. per inch tear strength.

CONTROLLED AIR FLOW NOZZLE

A rugged aluminum air nozzle which weighs less than six ounces, yet allows full control of air flow by the operator, is now on the market. Pressure from the thumb controls the amount of air released from a slight puff to full blast with no jumping from low to high or from high to low. The nozzle reduces air consumption and, as a safety factor, helps prevent chips blowing over the shop. With only two working parts and no springs, maintenance and replacement costs are almost eliminated. Each valve must pass an underwater test pressure of 100 lbs. psi to check for leakage before being ready for shipment. The nozzle is manufactured by Mortimore Mfg. Co., 72 Broadmere Rd., Stratford, Conn., information and literature are available.

DIAL SETTING CONTROLS PUMP

A simple dial setting regulates a new pump so that its capacity can be changed to suit the product being pumped. Slide rule calculations or gear changers are unnecessary; setting the dial maintains desired output capacity. The new pump can be used for blending and processing fuel oils, caustics, additives and other chemical products. Pump speed can be adjusted to handle products of varying viscosities. For further information on the Granco vari cap pump contact Granco Corp., Oakland, Cal.

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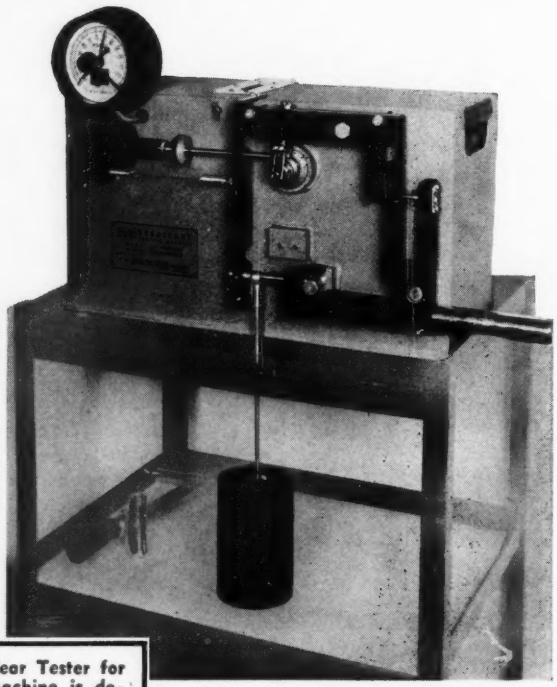
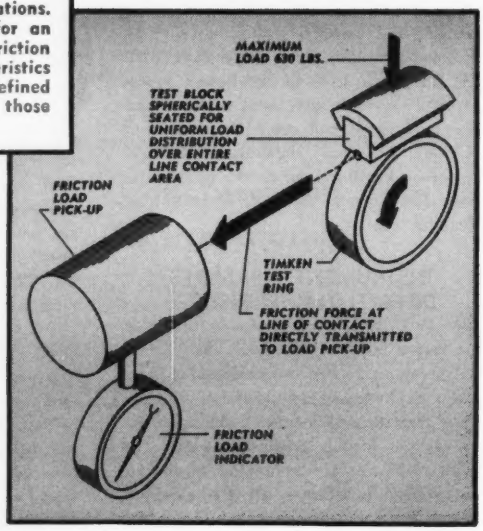
PRECISION TESTING IN THE LOW VELOCITY E. P. RANGE

Admittedly the greatest single handicap in boundary lubricant research has been the lack of tools in the form of accurate and reliable bench test equipment. The stark oversimplification of E.P. testing equipment contrasts sharply with the complexity of friction and wear phenomena. The Alpha Model LFW-1 is the result of a search for an "intermediate" between the oversimplified E.P. Bench Test and costly and time consuming full scale performance tests. Such intermediates, of which many are needed, cannot fail to sharply reduce the terrific waste of research expenditure and talent.

Since all E.P. lubricity ingredients function effectively only in a limited temperature range, E.P. Bench Tests must either measure frictional contact temperature or, pending the development of means to do so, simulate them. Sliding velocity is one important factor in this simulation. A large group of E.P. lubricity ingredients which are highly successful in industrial low velocity mechanisms completely fail to respond on most E.P. testers because excessive velocities and loads combine to produce frictional temperatures beyond the functional temperature range of the E.P. ingredient.



Alpha Model LFW-1 Lubricant-Friction-Wear Tester for sliding velocities below 43 feet per minute. Machine is designed for low velocity extreme bearing pressure applications. Developed by professional testing machine designers for an accuracy of better than 98% in load, velocity and friction measurements, results reflect the performance characteristics of a lubricant in a uniformly loaded and accurately defined friction area. The only variables from test to test are those intended by the operator.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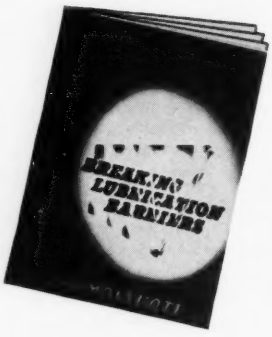

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Sectional Sustaining Members: are such persons or organizations as may be interested in and desire to contribute to the support of the purposes and activities of a local Section of the Society. Fee $25.00.

Industrial Members: Industrial Members are such persons or organizations as may be interested in and desire to contribute to supporting the purposes and activities of the Society. Fee $150.00.

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CURRENT LITERATURE

DRY FILM LUBRICANTS—Some dry film lubricants have high pressure and anti-wear properties as good as or better than extreme pressure oils, according to a report of tests conducted by the Air Force. The report has just been released for industry use through the Office of Technical Services, U. S. Department of Commerce.

The investigation indicated that the most successful types of dry film lubricants have excellent properties for plain bearing applications at low speeds. The dry-friction reducing films were tested for endurance and load-carrying capacity on the Falex Lubricant Tester. Materials studied were commercial baked resin-bonded films and spray can coatings with graphite or molybdenum disulfide, experimental baked resin-bonded films with molybdenum disulfide and a variety of resin bases, and air-drying coatings applied by dipping.

Among the results, it was shown that the life and load-carrying ability of dry film lubricants is dependent on the resin bonding agent used and the pretreatment given the metal surface. It was emphasized that maximum life is obtained if both bearing surfaces are coated. Endurance life of films containing molybdenum disulfide far exceeded that of films with graphite.

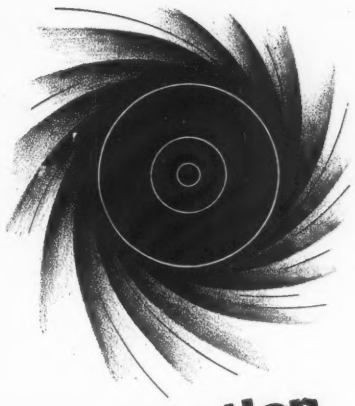
The report, PB 121922 *Evaluation of Dry-Film Lubricant Coatings, Part 1*, W. C. Hart, Wright Air Development Center, U. S. Air Force, Sept. 1954, may be ordered from OTS, U. S. Department of Commerce, Washington 25. It contains 29 pages, price 75 cents.

HIGH-TEMP BEARINGS—Nickel-base silver impregnated materials reported to have superior extreme-temperature characteristics have been developed for the Air Force.

The work was intended to extend the upper temperature limits of materials used for cages of bearings in gas-turbine jet engines, an improvement which would increase engine efficiency and power. The improved materials were to replace those already operating at their high-temperature limits.

Developmental work concentrated on various boride, carbide and silicide additions to a silver infiltrated nickel matrix produced by powder metallurgy. The borides were found to have the best properties. A 7 percent chromium boride addition was best among several compositions with superior wear characteristics.

The report, PB 121935 *Retainer Materials for Aircraft Gas-Turbine Bearings*, P. F. Mataich and F. C. Wagner, Horizons, Inc. for Wright Air Development Center, U. S. Air Force, Aug. 1956, may be ordered from OTS, U. S. Department of Commerce, Washington 25. It contains 34 pages, price $1.



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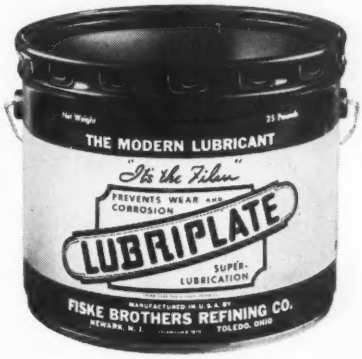


Lubrication Abstracts

(Compiled by the ASLE Abstracts Sub-Committees).

"Addition Agents for Lubricants". C. J. Boner (Battenfeld Grease & Oil Corp.). *Petroleum Engineer, v.* 28, *no.* 3, 1956, C53-6, C58, C60, C62, C64-5; *no.* 5, 1956, C28, C31-2; *no.* 9, 1956, C17-8, C22.

Eighteen different ways in which the properties of lubricating oils and greases are improved by additives are discussed. In each category, typical commercial compounds and dosages are given, and the methods by which they function are described. Particular attention is devoted to anti-oxidants and detergents. A bibliography is included. (*Abstractor: M. I. Smith*)

Circulating Oils. *Lubrication, v.* 42, 1956, 109-24.

The various types of circulating oils are identified by outlining the requirements for their use as crankcase oils in automotive and aircraft engines, for steam turbines, roll neck bearings in steel mills, and EP gear oils. The common types of additives are listed together with reasons for their use and their mechanisms of action. Data on oil-flow rates in piston type aviation engines are included. (*Abstractor: E. O. Forster*)

"Disposal of Spent Soluble Oil Emulsions." Anon., *Lubrication, v.* 43, *no.* 4, Apr. 1957, 41-8.

The nature and composition of waste materials discharged into public waterways are controlled by Federal, State, and many local laws. In many cases the waste water must contain less than 25 ppm of oil. It is best to separate spent soluble oil emulsions from other waste oils. The emulsion can be broken either by spent pickling acid or aluminum sulfate. It is then neutralized to pH 7-8 with caustic soda or soda ash. The mixture separates into three layers. The bottom floc is taken to the city dump. The middle water layer containing very little oil is put into the sewage stream. The top oil layer is skimmed off and used for road surfacing or further refined for use as fuel or lubricant. Similar procedures can be used for the separation of cutting oils and other industrial oils. (*Abstractor: A. S. Gressel*)

"Efficient Swarf-Handling & Oil Reclamation." Anon., *Machinery* (London), *v.* 90, *no.* 2323, 1957, 1153-1157.

Important economies are obtained by a system of recovery of cutting oil from swarf (grit from lathes or grindstones). The value of the scrap, which is practically oil free, is enhanced by the system. The different types of swarf such as aluminum, brass, cast iron, or steel are kept separate. Each machine is provided with a draining table where the swarf is kept for about twenty minutes so that the bulk of the oil is drained off. The swarf is then moved to a centrifuge where almost all the remaining oil is removed in 2½-3 minutes. The oil flows to a weir-type settling tank. The dry swarf is dumped on a floor where it is separated into coarse and fine grades each of which has a higher market value than the mix. The settled oil is pumped into a centrifuge where the balance of impurities is removed. The reclaimed oil is subjected to lab control and restored to the required quality by suitable treatment. (*Abstractor: A. S. Gressel*)

"Evaluating Oils by their Water Separation Tendency." H. W. Thoeues, Brennstoff Chem., *v.* 37, 1956, 336-41.

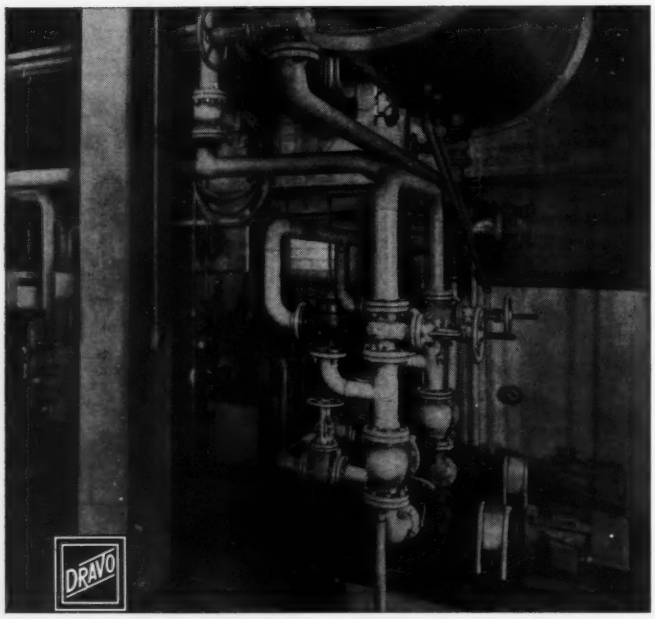
Current emulsification tests do not correspond to practical operating conditions encountered when water or steam enters a lubricating oil circulation system. A new method is described for determining the water separation tendencies of an oil. (*Abstractor: E. O. Forster*)

"Gas-Engine, Gas-Plant Lube Program." Edward D. Shannon, *The Oil & Gas Journal, v.* 55, *no.* 6, 1957, 102-5.

The results of a gas-engine-test and gas-plant-lubrication program are summarized in ten basic conclusions: (1) Detergent naphthenic oil is desirable for both two-cycle and four-cycle gas-engine service. (2) Cotton waste or cellulose-fibre filter elements are preferred for detergent oils. (3) Sight-feed mechanical bobbers or new vacuum-type lubricators are best for use with detergent oils. (4) Drain periods of gear-box oils should be frequent when first installed, then every six months. (5) Lead-soap EP gear lubricants are desirable to meet load conditions. (6) Multi-purpose

(Continued on p. 542)

DRAVO-DeLAVAL Lubrication Systems for Bowaters



Oil cellar for one of the lubricating systems at Bowaters Southern Paper Corporation, Calhoun, Tennessee.

Three Dravo-designed systems automatically lubricate the dryer roll sections of the huge Fourdrinier paper machines at Bowaters Southern Paper Corporation's plant at Calhoun, Tennessee. A fourth system supplies oil for fourteen pulp grinders of which six are driven by 6000 hp motors and eight by 4500 hp motors.

In service for more than three years, the lubricants have shown no change in viscosity, no oxidation, no water content and no acidity. The systems are equipped with micronic filters, centrifugal oil purifiers and include temperature and pressure controls, pumps, tanks, pressure reducing stations and control panels.

For full information on cost-saving Dravo-DeLaval Lubrication Systems, write for Bulletin No. 1450, DRAVO CORPORATION, PITTSBURGH 22, PENNSYLVANIA.

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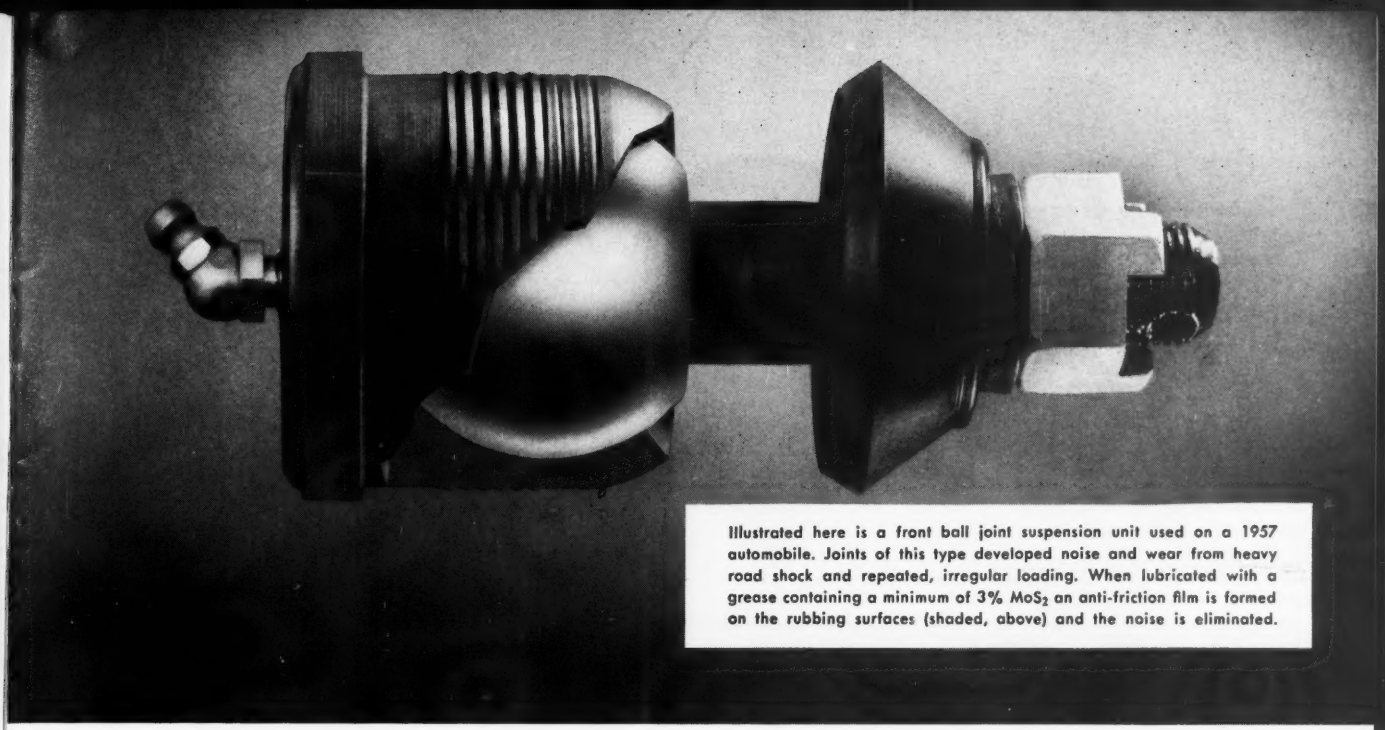

Illustrated here is a front ball joint suspension unit used on a 1957 automobile. Joints of this type developed noise and wear from heavy road shock and repeated, irregular loading. When lubricated with a grease containing a minimum of 3% MoS_2 an anti-friction film is formed on the rubbing surfaces (shaded, above) and the noise is eliminated.

When bearing surfaces are stripped of lubricants by SHOCK LOADING, OSCILLATION or RECIPROCATION . . .

MOLY-SULFIDE additive extends effective lubrication

Serious lubrication problems are often set up by extreme pressures, shock loading, oscillation and certain forms of reciprocating motion. Conventional lubricants may be forced out of the bearing area or wiped off the bearing surface. Then something more than a standard grease is required.

In situations of this kind, grease containing Moly-Sulfide proves its great value. MoS_2 is forced between the rubbing surfaces, adheres to the metal and forms a protective film that prevents galling, welding and fretting. The extent to which MoS_2 sustains lubrication is demonstrated by substantial reduction in wear, and is borne out by field reports from many different industries.

4 specific cases show advantages of MoS_2 for industry

Avoids splitting in steel punching. For example, while punching $\frac{5}{8}$" holes in $\frac{1}{2}$" thick hot rolled steel it was found that splitting of the plate frequently occurred between two adjacent holes, or toward the edge of the plate. This trouble, a result of heavy shock loading, was eliminated by brushing punches with lubricant containing MoS_2.

Makes excellent break-in lubricant for rocker arms. For break-in runs of engines, one of the major automobile manufacturers uses a supplemental MoS_2 grease on rocker arm pivots. The MoS_2 provides a low-friction film when the base lubricants wipe off under oscillating motion. This prevents galling and scoring of the mating surfaces.

Gives smooth travel to 4-ton grinding head. On a heavy cylindrical grinder the 4-ton head moves on the ways in a jumpy fashion, resulting in damage to the work. Use of a lubricant containing MoS_2 results in smooth, precise travel.

Serves well where lubricant cannot be resupplied. Moly-Sulfide is now widely used for lubricating such hard-to-reach points in automobiles as convertible top mechanisms, power operated windows and seat adjusters. Applied at assembly, the MoS_2 extends lubrication and greatly reduces noise and wear.

Many manufacturers now producing MoS_2 greases

Moly-Sulfide greases are available from many producers today. For a list of the manufacturers of these greases (Lu-2a) – which includes several major oil companies – and for a copy of "Molybdenum Disulfide as a Grease Additive" (Lu-17) write to Department 38, Climax Molybdenum Company, 500 Fifth Avenue, New York 36, N. Y.

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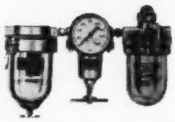

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ASPERITIES... *a page of editorial comment and opinion*

Technical Meetings-Are They Worthwhile?

Technical meetings are nothing new to most of us. We try to attend those that have some apparent value to us by offering solutions to current problems, discussions to improve our understanding of physical and chemical phenomena, or to participate in the long-range work and activities of technical societies.

What we take away from these meetings is often a measure of what we give to them. How important the individual meetings are to the progress of science can be measured indirectly through the response of other groups to the meeting through cooperative participation. Our recent joint conference on lubrication in Toronto is a perfect example. This is the first meeting held outside the USA by the Society. It featured two reporter sessions to include the results of work abroad as reported at the Institute of Mechanical Engineers' conference on lubrication and wear at London. Committee meetings were held to discuss the plans for research and future papers in numerous specialized interests of the Society. But why was the meeting so well attended?

No person can assimilate all the information presented during the meeting. Having preprints of the papers helps. Discussion from the floor, as well as an opportunity to ask questions of authors and other specialists, is possible only by attendance at the meeting. No transcript of the reporter sessions was available — even greater reason for attending.

How well has the committee organizing this meeting met the requests for information? Was the meeting valuable? In the survey questionnaire returned by last year's joint conference registrants the committee was asked for information on high-temperature lubrication, ball bearing lubrication, lubrication fundamentals, and extreme operating conditions. An examination of the recent program shows how well the committee fulfilled these requests. All of these factors — and many more — make these meetings important to attend, well worth the time and expense to you and your company.

In four years this conference has grown to the highest level of international recognition. For the first time in our history excellent papers have had to be refused for lack of time to present them. Standards for conference papers have become more rigid, and as a result, paper authors have had to supply greater effort and better papers.

The demand for preprints, in the period of two years that ASLE has been able to supply preprints of their meetings, can also be used to judge the importance of technical meetings. In the short period of time since releasing the program for this meeting the ASLE National Office has been deluged with orders for copies of the papers presented at Toronto. (A complete list will be found elsewhere in the journal.)

We may continue to improve the meetings of technical societies, but we cannot improve on the basic reasons for attending such meetings, wherever they may be held. Individual attendance is still the only way to satisfy the ever-questioning mind of the alert scientist.

R. D. McCormick

A Threading Test For Cutting Oil Evaluation

H. A. Hartung, J. W. Johnson and A. C. Smith, Jr., Atlantic Refining Company, Philadelphia, Pa.

A laboratory evaluation test for cutting oils based on the threading operation has been used successfully over a number of years for laboratory development work and for evaluation of field samples. The test involves generating a thread under regulated conditions and measuring the torque required. The equipment used is described in some detail, as are the factors which must be controlled carefully to make the test work. The geometry of threading processes is developed. Experimental laboratory data on a number of additives are included. Tool temperatures have been measured and found to agree well with other published data. Finally, correlation between laboratory and field results is shown to be good for a number of different machining operations.

For a number of years it has been apparent that adequate evaluation of cutting oils could be made only with a cutting process. Extreme pressure lubricant testers of one type or another have been used with success in certain instances for cutting oil rating, but data obtained with these devices have not generally correlated with field experience. Consequently, most laboratories engaged in this work have been forced to abandon EP testers in favor of one or more specific cutting operations[1-7].

To meet this situation in the authors' company, a critical survey of metal-cutting processes was undertaken. As a result of this study, the threading operation was selected as the most likely basis for a useful laboratory test. One principal reason for this choice was the fact that threading is a critical operation with regard to speed, and it was reasoned that it would reflect relatively small differences in cutting oil effectiveness.

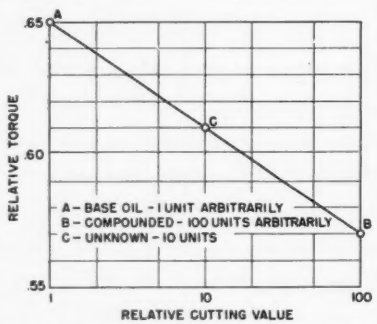


Fig. 1. Construction of cutting value scale.

From this starting point a test was developed, and experience has shown that the choice of the threading operation was sound. Over the years there have been some changes in method and equipment, but the basic elements of the original test remain. It has served well in the development of new products and in evaluation of field samples. It has given ratings which have been substantiated in many metal-cutting processes in the field.

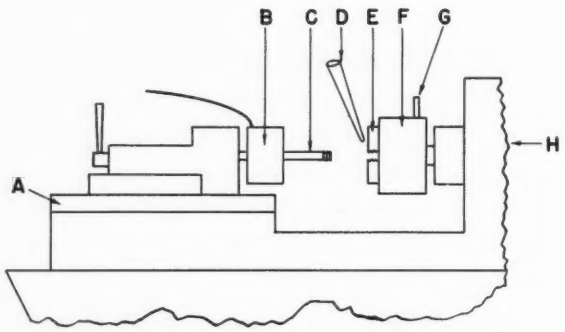


Fig. 2. Schematic view of laboratory threader. (A) Machine ways; (B) Dynamometer; (C) Test specimen; (D) Oil guide; (E) Chasers; (F) Rotating die head; (G) Opening lever; (H) Variable speed drive.

METHOD AND EQUIPMENT

The method involves generation of a thread on a specimen under closely controlled conditions. The torque required to produce the thread with an unknown oil is measured, and by comparison with torque values found for standard lubricant compositions, a relative rating can be put on the unknown oil. A numerical scale may be constructed, using a base oil and a highly compounded oil as the extremes. The torque values for these oils represent fixed points to which arbitrary cutting values may be assigned. Intermediate torque values then represent intermediate cutting values, and it becomes possible to speak of cutting oils in terms of performance numbers. Fig. 1 shows one method of setting up such a scale. Oils A and B are arbitrarily given values of 1 and 100 cutting units, respectively; Oil C, an unknown, gives a torque which corresponds to 10 cutting units. Obviously there are many variations possible; for instance, the arbitrary cutting values may be plotted arithmetically, or the line connecting the base points may be curved rather than straight. What relation the arbitrary cutting values have to field performance depends on the

Presented before the 12th Annual Meeting of the ASLE April 15, 1957 at Detroit, Mich.

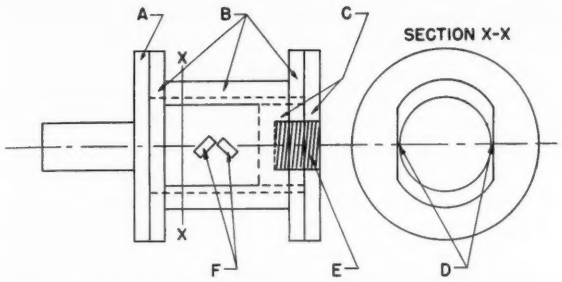


Fig. 3. Strain gage dynamometer for laboratory threader. (A) Steel end plate; (B) Aluminum active element; (C) Steel end plate; (D) Milled flats for strain gages; (E) Tapped recess for test specimen; (F) Strain gages.

manner of constructing the scale; our experience has been satisfactory using the method illustrated in Figure I.

The equipment (Fig. 2) consists of an H and G Threading Machine (Eastern Machine Screw Corporation) fitted with a style MM revolving die head. Four insert chasers generate the thread on a ¾" specimen which is held in a strain gage dynamometer (Fig. 3) specially constructed for this machine. Test oil is fed to the cutting zone through a single tube adjusted to discharge at the leading edge of the chasers. The strain gages on the dynamometer are connected in a bridge, the balance emf of which is traced by a recording potentiometer. The trace for each cut furnishes a visual record which can be examined in detail at leisure. A typical trace is reproduced in Fig. 4.

To make this test reproducible, strict control over a number of variables must be maintained.

A. **Specimens:** Only centerless ground bars are used as test specimens to eliminate geometrical errors. These are purchased in long lengths, color-coded, and cut into four-inch pieces. These pieces are de-burred, and pre-threaded for about ⅜ inch at each end. This is done to save the test tools and to eliminate differences in test results due to different starting pressures. Two tests can be run on each specimen. A number of different steels are suitable test materials, depending on the type of problem to be solved. Use of long bars cut into short lengths minimizes differences in test pieces. In practice, each long bar can be standardized by running two or three known oils on specimens cut from it. Threading torque is generally inversely proportional to machinability. (Table I)

B. **Chasers:** By running all tests on stock of constant diameter (¾") with chasers of the same pitch (0.0625"), the effects of diameter and pitch on threading torque (Table II) are eliminated. For this work only factory-ground chasers supplied by the machine manufacturer are used. This practice minimizes differences in metallurgy, heat treatment and grinding, and is recommended unless one has at his disposal adequate facilities for accurately re-

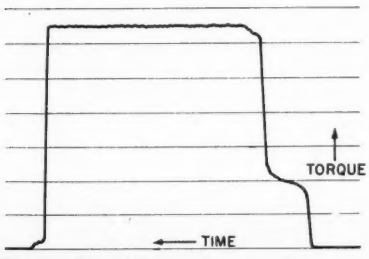


Fig. 4. Typical Torque-Time record.

grinding the chasers. The chamfer angle influences the threading torque moderately (Table III), but it affects tooth loading much more drastically. Fig. 5 shows how the chip thickness and the number of teeth generating the thread vary with the chamfer angle. It is apparent that with small chamfer angles, there are more teeth involved and the load on each tooth is less; consequently the threading job is easier. For this reason, the chamfer angle must be accurately controlled where it is desired to rate cutting oil performance. In this work, a 20° chamfer was used unless otherwise specified. The sharpness of the tool is also an important element in determining threading torque. In evaluating oils of low cutting ability, the observed torque may increase by 10% in as few as a dozen cuts with the same tool. Where oils of greater cutting value are being studied, the rate of wear is considerably less. A correction for this condition can be readily introduced by including periodic tests with a known oil in each series of cuts. Any drift in torque values with the known oil can be applied proportionately to the unknown oils of the series. This correction is usually necessary only in extreme cases. Generally, 50 cuts or more may be made with a set of chasers before replacement is desirable. Table IV shows results of 24 cuts with one set of tools on two different steels; it can be seen that the observed torques repeat rather consistently.

C. **Threading Speed:** Generally, threading speeds are 10-25% of the surface speeds recommended for turning. According to Table II, the effect of speed on torque is small; somewhat larger variations may be observed with different work-pieces. A standard speed of 56 surface feet per minute has been established for routine use in this test, but as the torque is rather insensitive to speed, precise control of speed has not been found to be necessary.

D. **Flow of Cutting Fluid:** The volume of the cutting fluid stream and the manner in which it enters the cutting zone are critical variables. The stream must be directed at an angle of about 60° with the horizontal, impinging on the work very slightly in front of the chasers. When so arranged, the oil stream floods the cutting zone. If the stream hits the rotating chasers, it is splashed before it can enter the region where the cutting takes place. The amount of oil to be used must be enough to cover the work during the five seconds or so when cutting is taking place; in most instances, a test can be run on 100 cc. of oil. Gravity feed under a head of about one foot is used. A satisfactory alternative is to pour the oil from a graduate into the cutting zone; this requires some slight skill on the part of the operator.

E. **Viscosity Effects:** Viscosity affects the torque values obtained in this test in two ways. First, it influences the flow pattern of the oil, and the angle of incidence of the oil stream may have to be reduced.

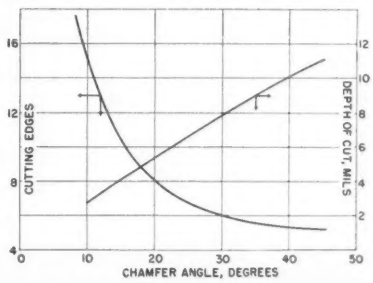


Fig. 5. Influence of chamfer angle on number of cutting edges and chip thickness.

low viscosity to keep them from splashing away from the cutting zone and giving falsely high torque readings. Second, there is a relation between optimum oil viscosity and threading speed, and a good oil of high viscosity may look poor if evaluated at too high a speed. Consequently, if this method is used to compare a group of cutting oil additives, all should be blended to nearly the same viscosity so that the results will not be influenced by viscosity effects.

GEOMETRY OF THREADING PROCESSES

The basic dimensions of a ¾ inch thread, National Fine Series, are shown in Fig. 6. For a single thread of given diameter and pitch, the number of cutting edges and thickness of the layer of metal removed by each edge (measured normal to the cutting edge) are determined by the chamfer angle θ and the number "f" of chasers or flutes in the threading tool. For this particular thread,

$$c = \text{maximum chip thickness} = \frac{p \sin\theta}{f}$$

$$= 0.015625 \sin\theta, \text{ and } N = \text{number of cutting edges}$$

$$= \frac{hf}{p \sin\theta \cos\theta} = \frac{5.19552}{\sin 2\theta}$$

The chip thickness calculated above is the maximum thickness of the undeformed chip. There will, of course, be portions of each chip which are thinner than this, and there will be chips cut by teeth at the ends of the chamfer which are in no part as thick as this computation indicates. The number of cutting edges given above is predicated on the chasers engaging the work to the standard thread depth. It is important to adjust the total depth of cut to the proper value, or to a standard value, because the total torque measured is the summation of the torques on each cutting edge. If the thread varies in depth, the number of teeth engaged will vary and torque values will reflect this variation. This is one principal reason for using centerless ground specimens.

EVALUATION OF ADDITIVES

As examples of one of the uses of this test, evaluations of several additives are shown in Fig. 7. These tests were run at constant speed, with oils of essentially the same viscosity; the test specimens were identical (347SS). Over the ranges shown, the plots are practically linear, although it is apparent that they should intersect at some point to the left where concentration is negligible. These data are useful in comparing additives and combinations thereof, and represent a convenient way of cataloging materials for purposes of formulation. In a particular application, however, involving a different steel, the relation among these additives might change.

Table I

Effect of Relative Machinability on Threading Horsepower at Constant Speed

Material	Relative Machinability	Relative Horsepower
Aluminum	250	45
Brass (free machining)	200	63
Screw Stock (B-1113)	135	100
1020 Steel	72	110
3135	52	121
2320	55	121
14% Chrome free machining	55	121
1045	57	127
1335	60	127
3140	42	137
347 Stainless	45	140
2330 Heat treated	—	147
1045 Heat treated	—	168
Chrome Nickel (88 Ni-12 Cr)	25	177

CORRELATION WITH FIELD SERVICE

The value of any laboratory test of this nature lies in its ability to predict what will occur in service. This method of rating cutting oils has been tested many times on a large variety of operations involving many different kinds of tools and work-pieces. For most operations, laboratory ratings have correlated with field performance virtually every time. Table V lists a few examples, involving competitive products as well as oils of known composition. In this table, all comparisons have been made at the same viscosity and machining conditions.

Unfortunately, the test falls down on such operations as grinding and honing. This may be expected from the nature of the cutting edges involved in these processes. One other area where it has not been completely successful is in the evaluation of soluble oils. It is able to rate a group of soluble oils in the proper order, but does not usually relate them properly to non-soluble oils. This phenomenon has been reported by others[5].

TOOL TEMPERATURE STUDIES

Some studies have been made of the tool-chip interface temperature using the tool-work thermocouple technique. To test the consistency of our data with that published by others, results from turning and threading tests

Table II Effect of Diameter, Pitch and Speed on Threading Torque

Diameter, inches	Threads per inch	Speed, RPM	Torque, ft.-lb.
¼	20	100	2
¼	20	200	2
¼	20	400	2
5/16	18	100	3¼
5/16	18	200	3¼
5/16	18	400	3¼
⅜	24	100	2
⅜	24	200	2
⅜	24	400	2
⅜	16	100	4¼
⅜	16	200	4⅜
⅜	16	400	4⅜
½	20	100	4⅛
½	20	200	4¼
½	20	400	4½
½	13	100	8
½	13	200	8⅝
½	13	400	9
⅝	18	100	6
⅝	18	200	6¼
⅝	18	400	6½
⅝	11	100	14
⅝	11	200	14¼
⅝	11	400	14½
¾	16	100	9
¾	16	200	9¼
¾	16	400	9½
¾	10	100	21
¾	10	200	22

Table III Effect of Chamfer Angle on Threading Horsepower

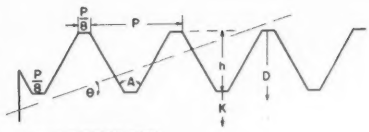
Steel	Threading Horsepower 10° Chamfer	20° Chamfer
B-1113	0.25	0.19
303 Stainless	0.35	0.30
347 Stainless	0.36	0.35
C-1095	0.50	0.52

Stock: ¾" diameter
Speed: 260 rpm
Tests run with the same cutting fluid

have been compared with data taken from the literature. For a plot of temperature vs speed, the agreement is fairly good with regard to both slope and level. Fig. 8 shows a comparison with data obtained on turning NE 9445 with carbide tools[8]. While the conditions are widely different in this and other published cases, general agreement is good.

The effect of oil quality on tool temperature was then examined. Fig. 9 shows the results for two different speeds. It is quite apparent that as the speed increases, the lowering of tool temperature (by direct cooling and by friction reduction) becomes more difficult.

These data are included because they illustrate an important point in the evaluation of cutting oils. The life of a tool is determined largely by the temperature at which it operates. Some element should be measured in a laboratory test that relates to tool temperature. This, of course, is not the entire story. The testing conditions must be realistic to duplicate the mechanisms of cutting oil action which apply in practice. As an illustration, log turning tests only give sensible results when production feeds and speeds are used; large increases in speed bring other mechanisms of action into effect and results are usually chaotic. Hence, to rate cutting oils, production conditions should be used; to accelerate the test, some element related to tool life should be measured. Threading torque is such an element. There are undoubtedly others; the radioactive tool, for example, measures directly (with more elaborate equipment) what we measure here indirectly (7).



n = 16 THREADS/INCH
P = 0.0625 INCH
D = 0.7500 INCH MAJOR DIAMETER
K = 0.6688 INCH MINOR DIAMETER
h = 0.04059 INCH BASIC THREAD DEPTH
S = 1°36' HELIX ANGLE AT PITCH DIAMETER
A = 60° THREAD ANGLE
P/8 = 0.00781 INCH BASIC FLAT WIDTH
θ = CHAMFER ANGLE

Fig. 6. Basic dimensions of ¾ inch National Fine Thread.

Table IV Observed Torque Data for Two Series of Cuts

Series I (Steel A, 56 sfm)

Oil	Cut number	Relative Cutting Value	Relative Torque
A	1	100	.53
B	2	100	.53
C	3	70	.54
D	4	50	.55
E	5	25	.57
F	6	150	.52
A	7	100	.53
G	8	70	.54
H	9	35	.56
I	10	1	.66
A	11	100	.53

Series B (Steel B, 56 sfm)

Oil	Cut number	Relative Cutting Value	Relative Torque
A	1	100	.54
J	2	140	.535
K	3	140	.535
L	4	350	.52
M	5	10	.57
N	6	3.5	.595
O	7	100	.54
P	8	9	.58
Q	9	16	.57
R	10	9	.58
S	11	9	.58
T	12	9	.58
A	13	100	.54

SUMMARY

This method of studying cutting oils has many features which are desirable:

1. It correlates well for most metal-cutting operations.
2. It is cheap to set up and run, and does not consume huge stocks of steel.
3. It can be run on four ounces of oil.
4. It does not require that skilled machinists conduct it.
5. The equipment requires little floor space.
6. The test can be run rapidly.
7. Tool availability is such that no tool grinding facilities are required for ordinary work.
8. It is not sensitive to particular additives.

On the other hand, it has a number of shortcomings:

1. It does not correlate well with abrasive processes.
2. It does not place soluble oils among straight oils.
3. The feed per revolution can be changed only by altering the tool.
4. The test is sensitive to viscosity differences.

Experience has shown that if proper attention is paid to the limitations of this test, it can be an extremely valuable laboratory tool. Compared with other methods of

Table V Relation Between Laboratory Evaluation and Field Performance for a Number of Machining Operations

Field Operation	Metal	Oil	Laboratory Cutting Units	Field Tool Life, hours
Threading & cutoff	1020	A	100	8
		B	150	12
	1020	C*	50	8
Tapping		D	90	10.5
Cutoff	1045	C*	50	8
Drill, chamfer and tap		D	90	12
	4140	E*	100	8
Turning	C-1117	F	150	10
		G*	6	8
	FSX-1117	H	6	8
		I*	20	8
Deep Drilling	Aluminum	F	150	40
	Bronze	J	5	Rate = 1"/hr.
		K	35	Rate = 4"/hr.
	1020	L*	120	10
		M	90	8
Cold Heading	M-2 HSS	N	81	18.5
Milling		O	31	10
		P	8	5.25

*Competitive Cutting Oil

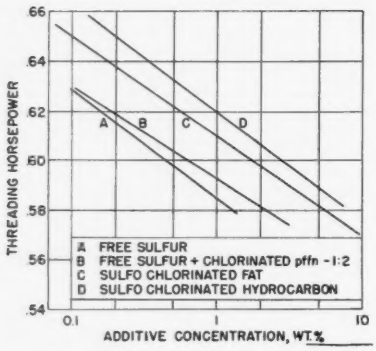


Fig. 7. Additive evaluation in threading test.

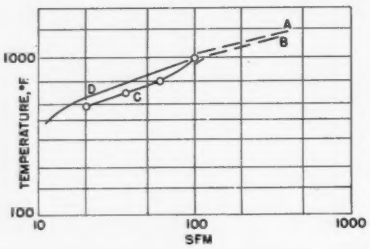


Fig. 8. Tool temperature as a function of cutting speed.

evaluating cutting fluid performance (9-11), a simple torque measurement has much to recommend it from the point of view of economy and simplicity.

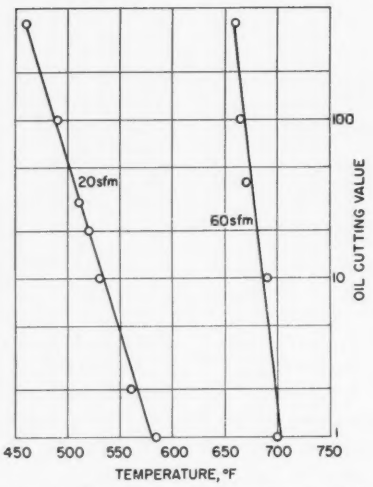


Fig. 9. The effect of oil quality on tool temperature.

BIBLIOGRAPHY

1. H. L. Moir, J. S. Yule, D. J. Wangelin & R. J. Moyer, "A Method for Testing Cutting Oils", *Lub. Eng.*, vol. 1, no. 1, (June, 1945) p. 12-20.
2. L. H. Sudholz, "The Evaluation of Cutting Fluids in Laboratory Equipment", *Lub. Eng.*, vol. 4, no. 1 (Feb., 1948) p. 18-24.
3. J. M. Stokely, "A New Performance Test for Cutting Fluids", *Lub. Eng.*, vol. 9, no. 3, (June, 1953) p. 137-139.
4. S. J. Beaubien & A. G. Cattaneo, "A Study of the Role of the Cutting Fluid in Machining Operations", *Lub. Eng.*, vol. 10, no. 2 (April, 1954) p. 74-79.
5. C. D. Flemming & L. H. Sudholz, "A Tapping Test for Evaluating Cutting Fluids", *Lub. Eng.*, vol. 12, no. 2 (June, 1956) p. 199-203.
6. A Dorinson, "Concentration Effects of Cutting Oil Additives in Performance Evaluation", *Lub. Eng.*, vol. 12, no. 6, (Dec., 1956) p. 387-391.
7. M. E. Merchant, H. Ernst & E. J. Krabacher, "Radioactive Cutting Tools for Rapid Tool-Life Testing", *Trans. ASME*, vol. 75, no. 4 (1953), p. 549-560.
8. K. J. Trigger and B. T. Chao, "An Analytical Evaluation of Metal-Cutting Temperatures", *Trans. ASME*, vol. 73, no. 1 (1951), p. 57-68.
9. W. E. Lauterbach & E. A. Ratzel, "Evaluating Cutting Oils by Determining their Effectiveness in Reducing Sub-Surface Grain Distortion", *Lub. Eng.*, vol. 8, no. 5 (Oct., 1952) p. 238-240, 261-262.
10. W. E. Lauterbach & E. A. Ratzel, "The Critical Rake Angle Method of Evaluating Cutting Fluids", *Lub. Eng.*, vol. 9, no. 6 (Dec., 1953) p. 313-315.
11. L. C. Hays & E. J. R. Hudec, "A Tool-Blade Wear Test for Cutting Fluids". *Lub. Eng.*, vol. 10, no. 1 (Feb., 1954) p. 20-23.

Note: Additional references to recent work may be found in "Bearing, Lubricants and Lubrication—A Digest of 1955 Literature", Mechanical Engineering, vol. 78, no. 8, (Aug., 1956) p. 703-714, and in Digests for previous years.

Acknowledgment

Much of the credit for the selection of this equipment and the development of this test must go to Mr. J. R. Waltman of our Domestic Marketing Department. Thanks are due to Messrs. J. F. McGrogan and A. H. Rudrauff, also of our Domestic Marketing Department, for making field test data available.

Lubrication Abstracts

(Continued from p. 534)

grease used sparingly gives best results with electric motor bearings. (7) When oil must be separated from steam condensate, compounded steam cylinder oil should be avoided. (8) Air compressor lubricant should be carefully selected to meet cylinder requirements and can usually be used in the crankcase. (9) Auxiliary engines can usually use gas-engine oil. (10) For pump lubrication premium multipurpose grease or premium rust and oxidation inhibited oil should be used. *(Abstractor: E. S. Reynolds)*

"General Purpose Greases." Anon. (The Texas Company). *Lubrication, v.* 42, *no.* 10, 1956, 125-132.

Some performance properties of several types of general purpose greases are discussed. It is pointed out that a grease which has the properties required to meet all conditions of operation has not yet been developed. *(Abstractor: M. I. Smith)*

"Grease Analysis." Anon. (The Texas Company). *Lubrication, v.* 42, *no.* 1, 1956, 1-12.

Some of the common ASTM and Federal Specification methods are described. The general characteristics of various soap-base greases are listed. *(Abstractor: M. I. Smith)*

"Lube Oil Tests Reveal Engine Ailments." J. L. Wilson, *Pipe Line Industry, v.* 5, *no.* 1, 1956, 25-9.

Spectrographic analysis of lubricating oil samples taken from engines reveals conditions of major engine components. Nearly 70% of the tests indicate possible ring and filter troubles, and 50% of bearing failures that occurred during the test were predicted. As experience is gained with this technique the accuracy of analysis improves and more reliable conclusions can be drawn. *(Abstractor: E. O. Forster)*

"A Mechanical Gardner Mobilometer." J. E. Roberts (Armament Research and Development Establishment, Fort Halstead, Kent), A. J. Taylor, D. E. Woods. *Journal of Scientific Instruments, v.* 33, *no.* 12, 1956, 499-501.

A mechanical version of the hand-operated Gardner Mobilometer is described. More rapid testing is obtained. Results on greases in the two models are in agreement. *(Abstractor: M. I. Smith)*

"Solubility and Viscosity Characteristics of Mixtures of Lubricating Oils and "Freon -13" or "-115." L. F. Albright and A. J. Mandelbaum, *Refrig. Eng., v.* 64, 1956, 37-47, 106.

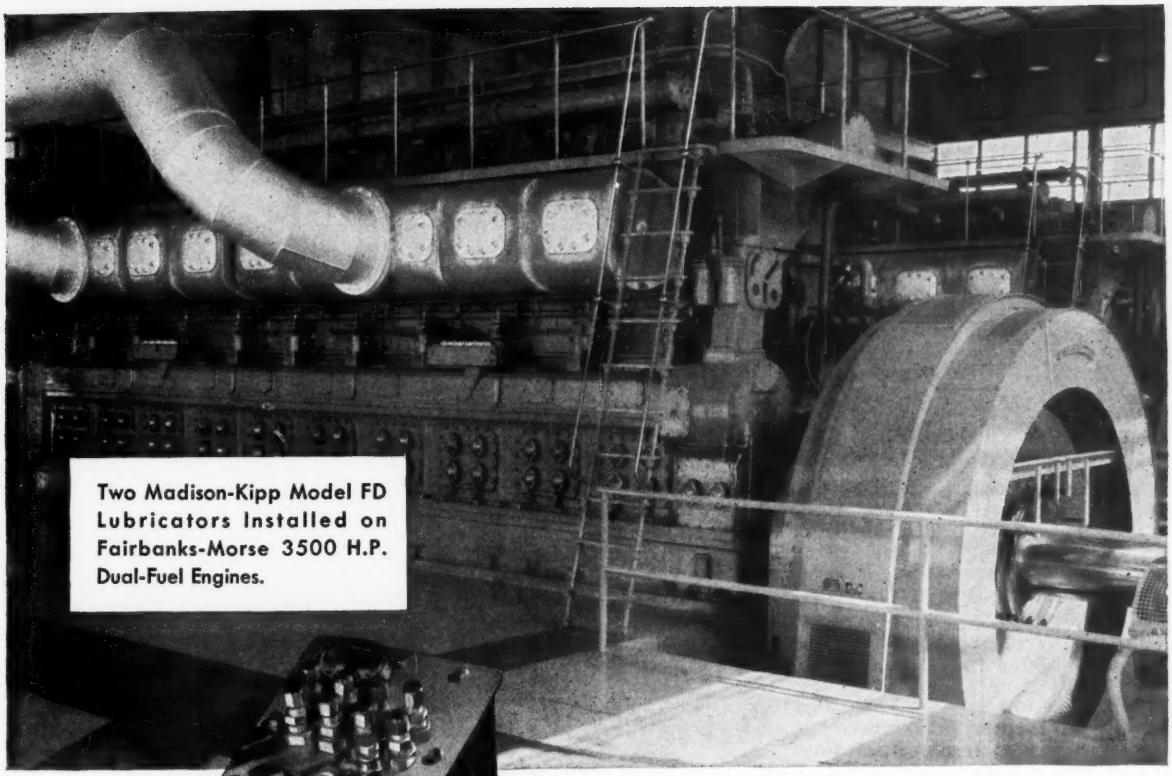
Absorption and viscosity data are reported for seven refined naphthenic or paraffinic-based lubricating oils with Freons-13, -115, and -22, at 50-150°F., and pressures up to those approaching the vapor pressures. The Freons were absorbed in all the oils in amounts increasing with increased Freon pressure and decreased temperature. All the Freons reduced the lubricating oil viscosity, the reduction being slightly greater for the naphthenic than the paraffinic oils. *(Abstractor: E. O. Forster)*

"Spontaneous Ignition Studies Relating to Lubricants of Reduced Flammability." K. T. Mecklenborg (Univ. of Cincinnati). NACA Technical Note 3560, Jan. 1956, 17 pp.

Results are given showing the effect of the alcohol group upon spontaneous ignition temperatures of azelaic diesters, phosphates, and phosphonates. An improved method of preparing hydrogenated polyisobutylene is described, and ignition characteristics of this material in blends with a siloxane and phosphonate are given. *(Abstractor: M. I. Smith)*

"Spray and Drip Methods of Applying Lubricant to Wire Rope." D. B. Burroughs, *Mechanization, v.* 20, *no.* 12, 1956, 65-7.

(Continued on p. 556)



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Current Literature

FILTRATION SYSTEM BOOKLET

The Industrial Filtration Division of the United States Hoffman Machinery Corporation has announced publication of a new four page, two-color brochure describing the parts, principles and application of Hoffman centralized filtration systems. Brochure FB-100 is available upon request.

AIR FORCE LUBRICANT STUDIES RELEASED FOR INDUSTRY USE

Useful techniques for analysis of synthetic greases have been developed recently for the Air Force and are described in a report just released to industry. Two related reports, one discussing gamma radiation effects on greases and the other reporting heat capacities of synthetic engine lubricants, also are available.

DEVELOPMENT OF SCHEMATIC ANALYTICAL PROCEDURES FOR SYNTHETIC LUBRICANTS AND THEIR ADDITIVES: Part 3. F. S. Bonomo, Denver Research Institute for Wright Air Development Center. Apr. 1957. 56 pages. (Order PB 131063 from OTS, U. S. Department of Commerce, Washington 25, D. C., $1.50.) Significant advances in techniques for the separation, identification, and determination of components of synthetic greases and lubricants were achieved during this work. Among them was the column participation chromatographic separation of high molecular weight dibasic acid esters from silicate esters, disiloxanes, and silicone oils. Adsorption analysis proved valuable for qualitative analysis of synthetic lubricants and base-oils, particularly when used for concentrating and identifying antioxidants and for removing impurities from a lubricant. A specific test for qualitative detection of selenium in synthetic oils and greases was developed. The technique utilizes sodium peroxide fusion followed by a spot test color reaction. Selenium was determined quantitatively by Parr oxygen bomb fusion. Still needed was a satisfactory method for detecting phenol-type antioxidants directly in lubricants. Attempts to remove phenol from the base-oil by volatization were unsuccessful.

THE EFFECTS OF NUCLEAR RADIATION ON MILITARY SPECIFICATION GREASES: Part 1. W. L. R. Rice, Wright Air Development Center, U. S. Air Force. Dec. 1956. 29 pages. (Order PB 121914 from OTS, U. S. Department of Commerce, Washington 25, D. C., 75 cents.) Many of the 47 greases tested appeared to be satisfactory for use after exposure to about 1×10^8 roentgens of gamma radiation. Of those which were affected, the major characteristic changes seemed to be in penetration (increased softening), oxidation resistance, and high temperature endurance life. Identification of the cause of these changes may pave the way for development of radiation resistant greases. The evaluation showed that a simple grease system would be best for use in a nuclear radiation environment. Fluids having individual radiation resistance may not be resistant after blending. Radiation seemed most harmful to some of the more promising high temperature grease formulations, particularly those containing polysiloxane base oils. Thus the development of new grease formulations may be necessary for use in high temperature applications under extremely high dosages of radiation. The report presents tabled data from the tests and recommendations for testing of irradiated greases.

HEAT CAPACITIES OF SYNTHETIC ENGINE OILS AND LUBRICANTS. H. Marcus, Wright Air Development Center, U. S. Air Force. Apr. 1957. 14 pages. (Order PB 131038 from OTS, U. S. Department of Commerce, Washington 25, D. C., 50 cents.) As a result of this research, an envelope of heat capacity variation for 11 synthetic lubricants was constructed. The envelope is of value to the design engineer for quick determination of a first approximation of data and for separation of average fluids from those exhibiting high or low heat capacities. The fluids fell under MIL-L-7808, a military lubricant performance specification, and were basically diesters of sebacic, azelaic, and adipic acids, high molecular fluoroester compounds, and silicones with small amounts of preservatives added. Heat capacity was measured on a modified adiabatic calorimeter designed to operate in the range of 100-500°F.

WORM GEAR BOOKLET

A 16-page, illustrated brochure — Finger Tip Facts on Cleveland Worm Gear Drives — provides useful summary information on the complete standard line of speed reducers, worm gear sets and special units manufactured by The Cleveland Worm & Gear Co. Bulletin No. 145 is available upon request from Cleveland, 3249 East 80th Street, Cleveland 4, Ohio.

HARDNESS TESTER DESCRIBED

A folder illustrating and describing the features of their 30-ounce portable tester which can be used in any position to test hardness of any size, shape or type metal has recently been issued by Newage Industries, Inc., 222 York Road, Jenkintown, Pa.

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Experimental Investigation of Railroad Journal Bearing Operating Characteristics

A. L. Busby, Douglas Aircraft Co., Santa Monica, Calif.
*G. L. Pigman, Caterpillar Tractor Co., Peoria, Ill.**

Measurements were made of the coefficient of journal friction and oil flow through the bearing for successive stages of seating of 6-in. by 11-in. babbitt railroad journal bearings. It is shown that the performance characteristics of the babbitt bearing do not change significantly with further wear after a seating width of about 2-in. is established. The time required to obtain this minimum seating width is increased with use of large initial clearance. About 200 miles is required in railroad service to obtain suitable seat width in a bearing with initial 0.015-in. radial clearance, and this clearance now has been accepted as standard by the Association of American Railroads. It is shown that measured friction agrees reasonably closely with computed values based upon *oil film cavitation*, whereas the theoretical friction curve based upon *negative oil film* pressures shows considerable deviation for conditions of large bearing loading. It is indicated from the measured and computed data that minimum friction occurs at a minimum oil film thickness of about 0.0002-in.

In September 1954, a comprehensive investigation** of the railroad freight car hot-box problem was completed. This investigation was concerned with all important technical phases of the hot-box problem, with the principal effort being directed toward obtaining a clear picture of the relationships existing between journal bearing performance, freight car truck cooling characteristics, operation of the waste pack lubricator, and lubricant requirements.

The railroad freight car journal bearing is a 120-degree centrally-loaded partial bearing with ¼-in. thick babbitt surface layer. In usual railroad practice, an initial radial bearing clearance of 1/64 in. to 1/16 in. is obtained when a new bearing is used on a new journal. When the journal is turned down to its minimum permissible size, an initial radial clearance of about ¼ in. exists when a new bearing is used.

At the beginning of the research program, specific data were not available to define basic properties of the railroad bearing such as its load capacity and friction characteristics, particularly under the variety of bearing fit conditions utilized in service. Data also were lacking concerning the bearing oil flow requirements, which are associated intimately with evaluation of the existing waste pack lubrication method. This paper presents data relating to the friction, load capacity, and oil flow properties of the railroad bearing, as obtained in one part of the broad investigation of the railroad hot-box problem. No attempt is made in the present paper to relate these bearing performance characteristics to broader aspects of the hot-box problem.

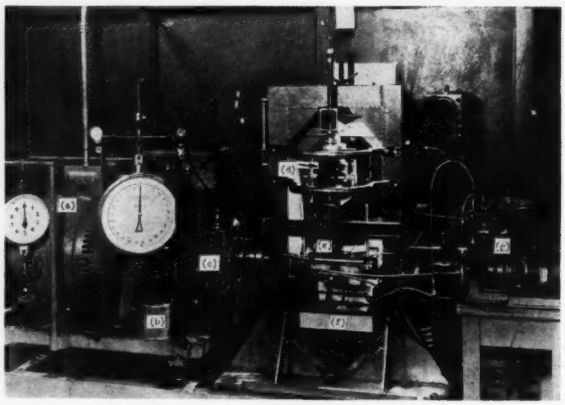

Fig. 1. Bearing test machine for evaluation of railroad journal bearings. (a) 20 HP Dynamometer, (b) Hydraulic Damper, (c) Truck Transmission Unit, (d) Spring Loading Mechanism, (e) Test Bearing, (f) Drain Pan, (g) Oil Feed System.

DESCRIPTION OF BEARING TEST APPARATUS

The test apparatus used in this investigation, shown in Fig. 1, utilizes a 6-in. diameter journal and a 6-in. by 11-in. bearing mounted between two supporting roller bearings. The journal is driven by a 20-hp variable speed electric dynamometer through a speed reducing unit. Both the motor and speed reducing unit are cradle mounted to provide measurement of reaction torque. Measured torque values must be corrected for friction of the roller bearings, such calibration being obtained by replacing the journal bearing with two equally spaced roller bearings identical to those used for journal support.

From the roller bearing calibration, it was found that the roller bearing torque and the test bearing torque are equal when the coefficient of friction of the test journal is about 0.001. In practice it was found that measured

*Research performed while authors were employed by the Armour Research Foundation.

**Made by the Armour Research Foundation under the sponsorship of the Association of American Railroads.

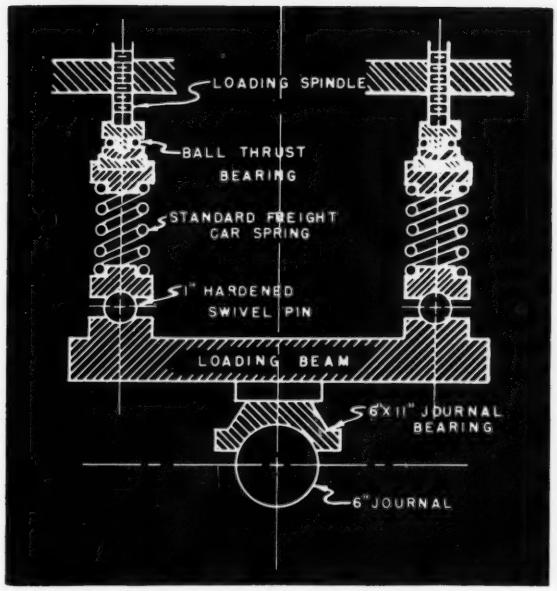

Fig. 2. Schematic diagram of bearing loading arrangement.

minimum values of journal coefficient of friction of about 0.0003 for the test bearing can be repeated consistently with different bearings, although the absolute value may have appreciable error in this range.

The diameter of the journal used in the tests was measured to be 6.005 in. The journal was ground initially to a measured surface roughness of 16 microinches, rms.

Oil is supplied to the test bearing in excess quantity by a pump and overflow trough. Close control of oil temperature is provided over a range from about 70°F to 270°F. Oil temperature measurements were obtained with a thermocouple placed in the center of the bearing closely below the babbitt bearing surface. It was found that measurements obtained in this manner are in close agreement with the average of those obtained in the bearing clearance gap at both ends of the oil film.

The load is applied to the bearing by two springs which are compressed separately by threaded spindles,

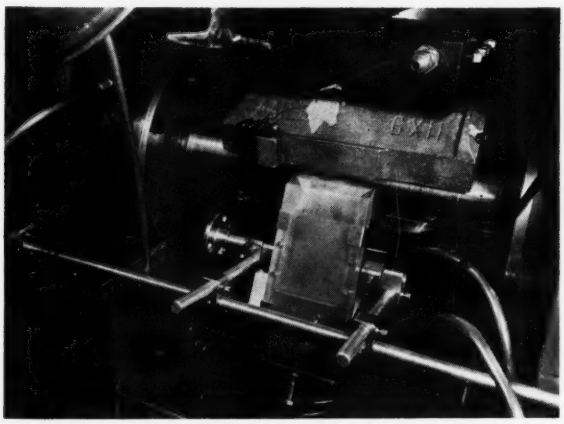

Fig. 3. Apparatus for measurement of oil flow through bearing.

and which provide a maximum total bearing load of 30,000 lb. Measurement of bearing load is obtained from the spring deflection as indicated by dial gages. As shown by Fig. 2, the loading system is constructed in the form of a parallelogram which allows the bearing freedom of movement in a lateral direction with respect to the journal, so that the bearing can seek its natural eccentric running position.

In addition to the above equipment, an arrangement is also provided to give qualitative indication of the various stages of oil film breakdown. This is accomplished by making electrical connection to the rotating journal through a mercury pool commutator and placing a potential of about 1.0 mv across the oil film in the bearing. The resulting current is indicated by means of a d-c amplifier and cathode ray oscillograph. No attempt is made to measure quantitatively the electrical current through the oil film.

TEST PROCEDURE

To best evaluate bearing performance for different amounts of bearing wear and fit, it was considered desirable to relate measurements of journal friction and oil flow to the commonly used parameter ZN/P, where Z is the oil viscosity in centipoise, N is the journal rotation speed in rpm, and P is the unit loading of the bearing in pounds per square inch. Each bearing test was started at a large value of ZN/P and then carried well beyond the minimum friction point in order to establish characteristic performance curves. Throughout the full test range the oil feed to the bearing was kept in excess of requirements, so that part of the oil was always rejected on the inlet side of the bearing.

The test bearings discussed in this paper are the standard 6 in. by 11 in. railroad journal bearing (1/64 in. to 1/16 in. radial clearance), and two other standard bearings which were machined to radial clearances of 0.003 in. and 0.250 in. (This latter clearance is common and may even be exceeded in present railroad practice.) For each of these bearings the characteristic curves for friction and oil flow were first determined for the unworn condition. Then, by continued testing, such performance curves were established for successive stages of bearing wear as the babbitt wear pattern increased from the initial condition of approximate line contact to the point where the bearing was well seated on the journal.

Oil flow measurements were made with a plastic scraper device (Fig. 3) which removes oil from the center portion of the journal on the exit side of the bearing. This device was found to give relatively high efficiency of oil removal (with only a trace of oil being picked up by a clean cotton pad when pressed against the journal behind the scraper). It is expected that appreciable error in measurement exists with this method, however, when the thickness of the oil film scraped from the journal reduces to a few ten-thousandths inch.

TEST RESULTS

Journal Friction and Bearing Wear

Results of the initial test of a bearing having approximately 0.033 in. radial clearance are shown by curve A of Fig. 4. It is seen that a minimum coefficient of friction of about 0.0006 is obtained at a ZN/P value of about 8. Although limitations of the test apparatus prevent reaching extremely small values of ZN/P, the test range

shown in Fig. 4 includes all normal railroad operating conditions and extends well into the region of oil film breakdown.

Further testing of this type showed improved operating characteristics with each succeeding test as the bearing became better seated on the journal. After five tests with the 0.033 in. clearance bearing (each test involving about one hour operation in the oil film breakdown region), the babbitt wear pattern increased to a width of 1½ to 2 inches, and the friction characteristics were improved to the condition given by curve B, Fig. 4. Minimum friction now occurs at a ZN/P value of about 4 with a minimum friction coefficient of about 0.0003.

Continued testing with this bearing showed no further improvement with regard to load capacity and friction, even though the wear pattern continued to increase in width as the bearing became better seated. Thus, curve B represents the final limiting friction characteristics of a well seated 6-in. diameter railroad journal bearing. These tests were repeated with two other bearings having radial clearance of 0.029 in. and 0.037 in. and very similar results were obtained.

The initial friction characteristics of a new bearing with 0.250 in. radial clearance on a 6-in. diameter journal are given by curve C of Fig. 4. This case corresponds generally to the practical condition in railroad service where the journal is turned down to the extent that it provides 0.250 in. or more radial clearance with a new bearing. It is seen that at high ZN/P values, the friction is about twice as large as obtained for a well seated bearing, and that minimum friction is obtained at a ZN/P value of about 40, which is about 10 times greater than the value for the well seated bearing.

Further testing of the large clearance bearing showed the same tendencies for wear and self seating as were found with the bearing with 0.033 in. clearance. However, the increase of babbitt wear pattern width and improvement in the friction characteristics proceed at a much slower rate. As mentioned previously, the 0.033 in. clearance bearing requires about 4 or 5 tests (each with about 1 hr operation time in the wear region) to reach a 1½ in. to 2 in. wear pattern width and acquire the final stable operating characteristics. It was found that after the 0.250 in. clearance bearing had been subjected to twice this amount of wear time, the bearing still does not demonstrate operating characteristics as good as those of the 0.033 in. clearance bearing without previous wear (curve A in Fig. 4). When the large clearance bearing finally develops a 2 in. wide seating width, however, it also acquires the same operating characteristics as described for the well-seated bearing (curve B, Fig. 4).

Although correlation between wear time in the laboratory and that obtained in freight car service has not been established, it is concluded from these results that a new bearing with 0.250 in. radial clearance will require considerably longer time to become properly seated than a new bearing with the nominal 0.033 in. initial clearance. During this wear-in period, unfavorable operating characteristics are exhibited in the form of greatly reduced load capacity and increased friction.

The friction characteristics measured during the initial test of a bearing with 0.003 in. radial clearance are presented in curve D of Fig. 4. These results show that at high ZN/P values the magnitude of friction coefficient is close to that obtained for a new bearing with large clearance. With decreasing ZN/P, the friction curve approaches that of the well-seated bearing. The observed upward shift of the curve at high ZN/P values is associated with effects of small clearance which are shown later in connection with the correlation of experimental data with theory.

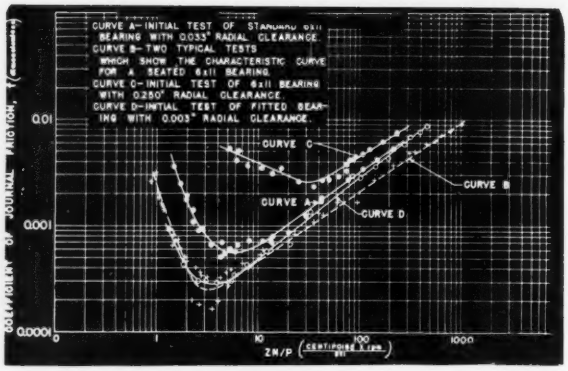

Fig. 4. Variation of journal friction with ZN/P, for four conditions of bearing clearance and wear condition.

Further testing and wear of the fitted bearing produced essentially no change in the friction curve (curve D of Fig. 4), indicating that by initially fitting the bearing with small clearance the effects of wear-in are negligible.

The photographs of Figs. 5 through 8 show the babbitt wear patterns obtained during the tests described above. It is seen in Fig. 8 that the close-fitting bearing reaches the desired seating width during its initial test.

Since it was found that the desired bearing seating surface at the crown of the bearing should be 1½ to 2 in. wide, tests were conducted by the Association of American Railroads to determine a practical value of radial clearance which would quickly provide this condition of bearing contact. With a clearance of 0.015 in. it was found that the proper bearing contact was obtained in the equivalent of 200 car miles.

As a result of these tests, the clearance of 0.015 in. has been made standard by the Association of American Railroads.

Oil Flow Measurement

The measured volume of oil scraped from the journal surface on the outlet side of the bearing over a given time (with the journal surface speed and the scraper length known) can be expressed conveniently in terms of the corresponding oil film thickness (h_m) at the point of maximum oil pressure in the bearing. As it is known from theory that a linear velocity distribution exists across the oil film at this location, the following relationship exists between these quantities:

$$h_m = \frac{2Q}{U}$$

where h_m = oil film thickness at point of maximum pressure in bearing, inches
Q = measured rate of oil flow, cubic inches per second per inch of journal length
U = journal surface velocity, inches per second

The value of h_m generally has no simple relationship with the minimum oil film thickness (h_o) in the bearing, but it does indicate in a convenient way its approximate

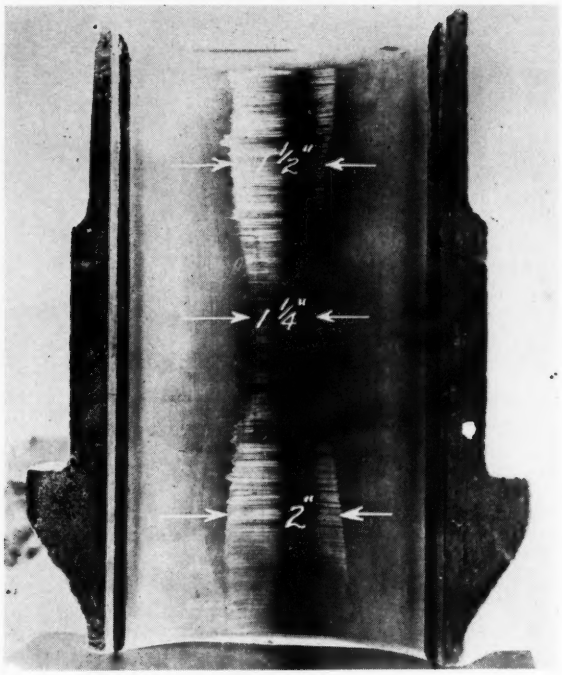

Fig. 5. Slightly worn standard 6 x 11 bearing, showing minimum desired seating width.

magnitude. For the high loading conditions on the bearing (low values of ZN/P), the angle between the point of maximum oil pressure and the point of minimum oil film thickness in the bearing becomes small, and the value of h_m more closely expresses the true value of h_o.

For small bearing loads (very large values of ZN/P corresponding to the Petroff condition) the value of h_m tends to approach the value of radial clearance c existing in the bearing.

To aid in such physical interpretation, the oil flow data obtained with the railroad bearings having different initial clearance and various stages of wear are plotted in Fig. 9 to show the variation of h_m with ZN/P.

It is seen by curve A of Fig. 9 that, because of the high unit loading which exists in the narrow load carrying area of the bearing with 0.250 in. radial clearance, thin oil films are obtained at relatively high values of ZN/P. When the radial clearance is reduced to 0.033 in. (curve B) the film thickness at a given ZN/P value is substantially increased and the operating range (prior to initial oil film breakdown) is extended to lower ZN/P values.

As the bearing begins to wear and increase the effective bearing area, the true bearing clearance and unit loading are reduced. The oil film then becomes thicker at a given value of ZN/P, and the bearing operation is extended to lower values of ZN/P before initial oil film breakdown occurs. This improvement continues until the bearing becomes well seated on the journal, at which time the limiting characteristics given by curve C are obtained where no further change is observed with added bearing wear.

Oil flow data were not obtained during the initial test of the fitted bearing with 0.003 in. radial clearance. However, such measurements were made after this bearing had received a small amount of babbitt wear. It is shown for this condition (curve D, Fig. 9) that the h_m curve coincides with that of the well seated bearing at low ZN/P, and then flattens out at high ZN/P and appears to become asymptotic to a film thickness value of about 0.0023 in. It is indicated, for reasons previously discussed, that this value is the approximate effective radial clearance of the fitted bearing for the particular stage of wear which existed during this test.

A comparison of curve D with curve C indicates that, at low ZN/P, the operating characteristics of a seated bearing (having initial large clearance) are determined by the small radial clearances which exist in the center worn portion of the bearing. At high ZN/P values, more of the bearing width is being utilized, and the effective clearance value is an average of the small clearance in the bearing center and the original large clearance of the unworn portion.

An additional significant conclusion obtained from Fig. 9 is that correlation of h_m values with the minimum friction points on the coefficient of friction curves for the well-seated and the small clearance bearing (Fig. 4) shows that a film thickness value of approximately 0.0002 in. exists at the beginning of oil film breakdown. As the value of ZN/P corresponding to this condition is relatively small, the above value of 0.0002 in. for h_m probably corresponds approximately to the limiting magnitude of h_o, the minimum oil film thickness.

Visual Indication of Oil Film Breakdown

Oscillograph patterns were obtained during test of a well seated bearing, indicating the variation of electrical resistance across the oil film. These patterns illustrate

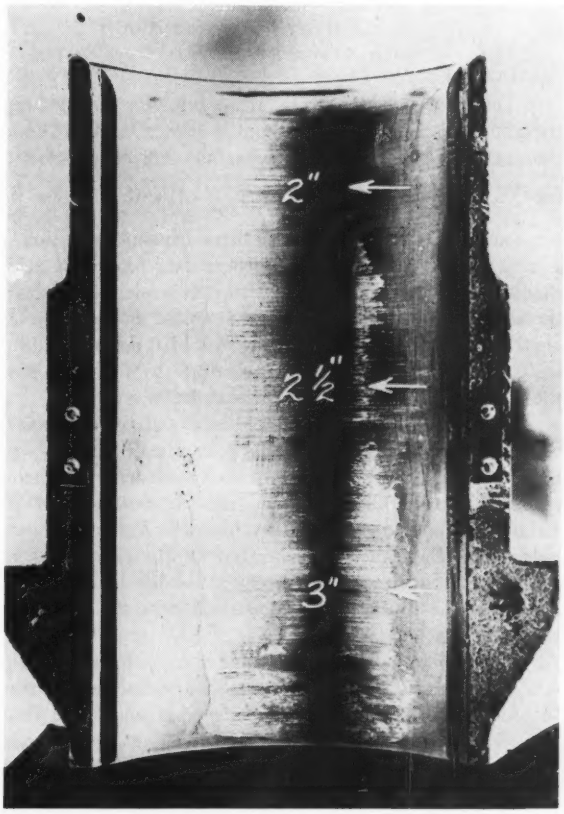

Fig. 6. Wear pattern of a seated 6 x 11 bearing.

the manner in which oil film breakdown progresses with decreasing value of ZN/P.

For values of ZN/P greater than about 50, the oil film is sufficiently thick to insulate fully, so that no appreciable current flows through the film. With decreasing ZN/P intermittent metallic contact occurs, which causes signal pulses to appear during each instant of contact. When a ZN/P value of 8 is reached, almost continuous metallic contact exists through the oil film through numerous small points, although the low magnitude of friction at this value of ZN/P indicates that hydrodynamic lubrication still largely exists. This condition marks the beginning of oil film breakdown as observed on the friction curve.

CORRELATION OF EXPERIMENTAL DATA WITH THEORY

As the initial radial clearance is known for these test bearings, that portion of the experimental friction and oil flow data which is obtained before babbitt wear begins can be compared with values computed from theory. As it is desired to obtain a direct check with results of theoretical analysis of partial bearings which was carried out in an earlier phase of the research program[1], the test data are plotted in terms of the "load factor $\triangle$ rather than the Sommerfeld number. The load factor is inversely related to the Sommerfeld number by the factor $1/\pi$ and is defined as follows:

$$\triangle = \frac{W}{\mu U L}\left(\frac{c}{R}\right)^2$$

where W = bearing load, lb.
L = bearing length, in.
μ = oil viscosity, reyns
U = linear journal surface speed, in./sec.
c = radial bearing clearance, in.
R = journal radius, in.

Oil Flow Factor (k_m)

Taking the values of h_m from Fig. 9 and applying the appropriate value of radial clearance c for the fitted, standard, and oversize bearings, the variation of oil flow factor $k_m\left(=\frac{2Q}{Uc}=\frac{h_m}{c}\right)$ with load factor can be established for these three bearing conditions. Fig. 10 shows the measured oil flow data plotted in this manner for comparison with the previously established theoretical relationship[1]. The theoretical curve is for a centrally-loaded, partial bearing of 110 degree width, which is approximately the angular width of babbitt for the standard 6 in. by 11 in. railroad bearing.

It is shown in Fig. 10 that the 0.0023 in. clearance value used for the fitted bearing (as indicated by the h_m curve in Fig. 9) provides good agreement with the theoretical k_m curve. The method used for determining effective clearance of this bearing from the h_m curve guarantees that the experimental value of k_m will approach unity, and thus check with theory, at the low load factors. However, it is found that a good check with theory is obtained also at large load factors.

Data obtained for the standard new bearing with 0.033 in. clearance also shows good agreement with the theoretical oil flow factor curve except at small load factors, where a maximum difference of about 50 per cent is observed.

Measured oil flow factors for the bearing with 0.250 in. radial clearance show reasonable agreement with theory, except at large load factors where the values of k_m are about three times greater than the computed values. It will be shown in the following section that this discrepancy probably is associated with a reduction of radial clearance (to an unknown degree) caused by initial oil film breakdown and babbitt wear which starts at a load factor value of about 3000. As the clearance value is not known after babbitt wear begins, true values of k_m and load factor cannot be plotted.

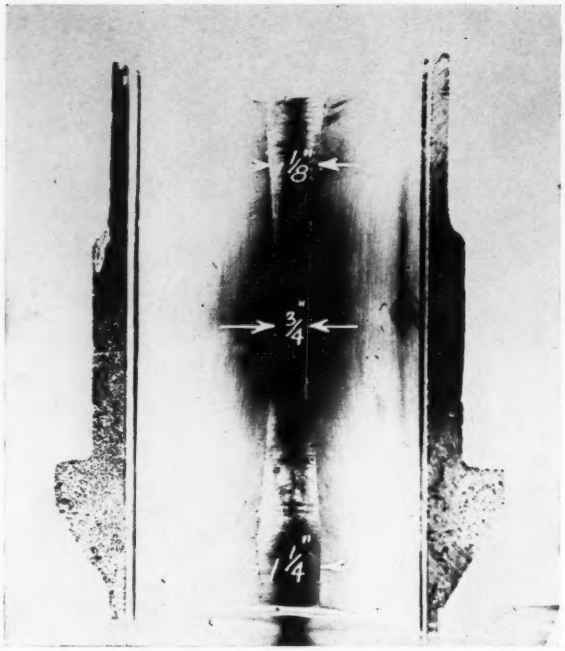

Fig. 7. Wear pattern of bearing with 1/4 inch clearance (subjected to twice as much wear as bearing in Fig. 5.)

Coefficient of Friction Factor $f(R/c)$

It is expected from previous analysis[1] that the coefficient of friction factor should follow a linear relation-

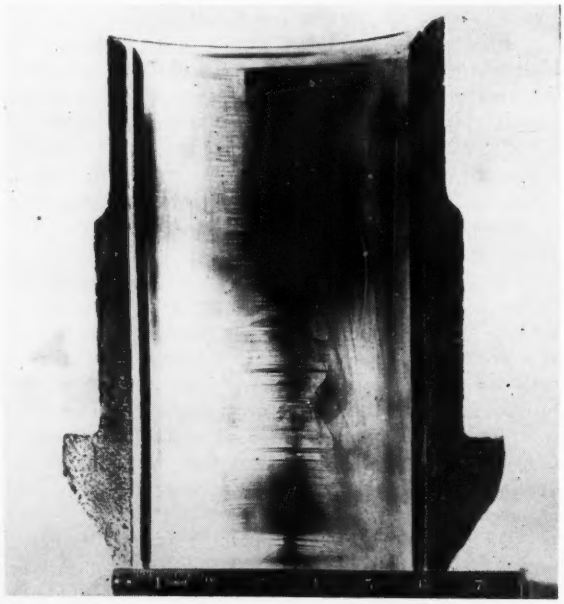

Fig. 8. Wear pattern after initial test of fitted bearing.

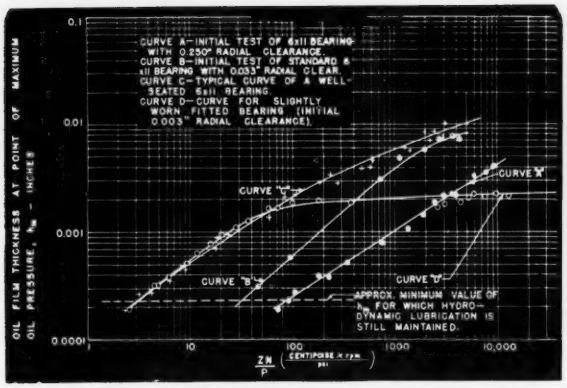
CURVE A—INITIAL TEST OF 6x11 BEARING WITH 0.250" RADIAL CLEARANCE.
CURVE B—INITIAL TEST OF STANDARD 6x11 BEARING WITH 0.033" RADIAL CLEAR.
CURVE C—TYPICAL CURVE OF A WELL-SEATED 6x11 BEARING.
CURVE D—CURVE FOR SLIGHTLY WORN FITTED BEARING (INITIAL 0.003" RADIAL CLEARANCE).
CURVE A
CURVE C
CURVE B
CURVE D
APPROX. MINIMUM VALUE OF h FOR WHICH HYDRODYNAMIC LUBRICATION IS STILL MAINTAINED.
OIL FILM THICKNESS AT POINT OF MAXIMUM OIL PRESSURE, h (INCHES)
0.1
0.01
0.001
0.0001
10
100
1000
10,000

Fig. 9. Variation of oil film thickness at point of maximum oil pressure with ZN/P, for four conditions of bearing clearance.

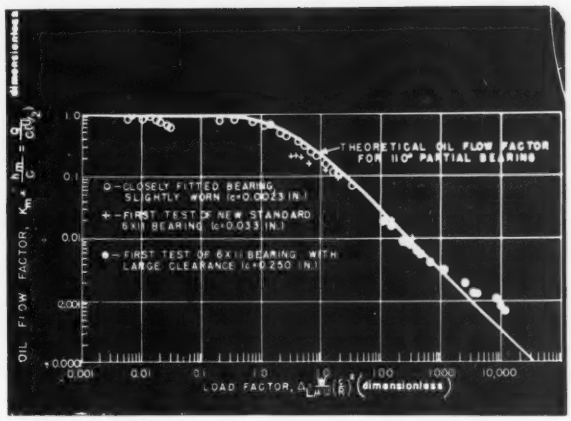

Fig. 10. Variation of theoretical and experimental oil flow factor with load factor.

ship with load factor in the low load factor range, corresponding to a lightly loaded (Petroff) bearing condition. At large load factors, assuming the occurrence of oil film cavitation rather than the existence of negative pressures under the exit side of the bearing, the coefficient of friction factor varies in a straight line relationship (on log log plot) with load factor, with a slope of slightly less than minus 0.5. The coefficient of friction factor approaches zero at large values of load factor. This relationship is shown in Fig. 11 for the 110 degree partial bearing. The inflection of the curve at a load factor value of about 4 occurs at the transition from the lightly loaded (noncavitation) condition to the heavily loaded (cavitation) condition.

The results of Howarth[2] also have been plotted in the nomenclature of this paper and are shown by the dotted curve of Fig. 11. In Howarth's work, the friction computations were based upon the assumption that the effective oil film, including a negative pressure region, extends over the entire angle of embrace of the bearing. Therefore, the load carrying capacity was computed as the vector sum of the pressure forces in both the positive and negative pressure regions. Howarth's calculations, as shown by Fig. 11, were carried to a load factor of about 10.

For purpose of comparison with the cavitation theory, analysis based upon existence of negative pressures has been extended to greater load factors, and this extension is also shown in Fig. 11. This friction curve turns upward away from the cavitation curve and approaches a value of $f(R/c)$ equal to unity at large load factor. It is seen that at small load factors (below about 6) the two curves coincide, but in the large load factor range the two methods of analysis give different results.

Superimposed on the theoretical curves of Fig. 11 are measured friction data, shown previously in Fig. 4, for the initial tests of the fitted bearing, the standard bearing, and the bearing with large clearance. As the radial clearance of the fitted bearing is estimated for one particular stage of wear (0.0023 in. as determined by oil flow measurement), the friction data for this condition also are plotted for comparison with theory.

Bearing With 0.0023 in. Radial Clearance

It is seen by Fig. 11 that the measured coefficient of friction factor for the bearing with 0.0023 in. radial clearance is in relatively good agreement with the theoretical curve over the entire operating range, and that minimum friction occurs at a load factor of about 25. At this load factor value, it is shown by Fig. 10 that the measured oil flow factor (k_m) is 0.1, again in agreement with theory.

The computed minimum film thickness ratio h_o/c can be used to estimate the limiting minimum film thickness (h_o) at beginning of oil film breakdown. To provide this additional information, the computed variation of h_o/c with load factor[1] has been reproduced in Fig. 11. Using the 0.0023 in, radial clearance value and the minimum film thickness ratio given by the theoretical curve ($h_o/c = 0.086$), the computed minimum film thickness which exists at the point of beginning oil film breakdown ($\triangle = 25$) is found to be about 0.0002 in.

Bearing With 0.003 in. Radial Clearance

It is shown by Fig. 11, for the bearing with 0.003 in. radial clearance, that the measured friction begins to deviate from a straight line relationship at a load factor of about 30. For all data obtained at smaller load factors (in the region of full hydrodynamic lubrication) close agreement with theoretical friction values is observed.

For this load factor of 30 the theoretical curve in Fig. 11 gives a value of (h_o/c) of 0.074. From this ratio a value of h_o equal to about 0.0002 in. is computed, which compares closely with the limiting minimum film thickness for the bearing with 0.0023 in. clearance.

Bearing With 0.0023 in. Radial Clearance

Experimental friction data for the standard bearing with 0.033 in. radial clearance are found to follow reasonably closely to the theoretical curve based upon oil film cavitation, rather than to the theoretical curve based upon negative oil film pressures, as shown in Fig. 11. It is indicated from such data that consideration of oil film cavitation is required to provide reasonable agreement between computed and measured friction values in this operating region.

It is shown in Fig. 11 that minimum friction occurs with this bearing at a load factor of about 3000. For the given value of radial clearance, this load factor would correspond to an extremely small magnitude of h_o, as indicated by the theoretical value of $h_m = 0.000033$ in. obtained for this load factor from Fig. 10. This result appears to be inconsistent with the limiting values of h_o obtained with the smaller clearance bearings.

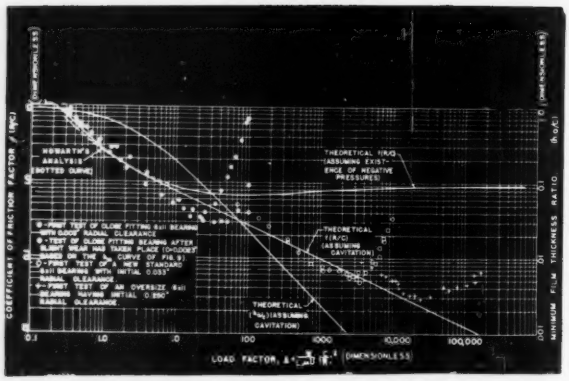
COEFFICIENT OF FRICTION FACTOR f (ηN/P)
MINIMUM FILM THICKNESS RATIO h₀/c
HOWARTH'S ANALYSIS (DOTTED CURVE)
THEORETICAL f(R/c) (ASSUMING EXISTENCE OF NEGATIVE PRESSURES)
THEORETICAL f(R/c) (ASSUMING CAVITATION)
THEORETICAL h₀/c (ASSUMING CAVITATION)
LOAD FACTOR, A = ZN/P (DIMENSIONLESS)

Fig. 11. Variation of theoretical and experimental coefficient of friction factor with load factor.

It is indicated from consideration of the film thickness data of Fig. 9 that the limiting value of minimum oil film thickness probably is reached with this bearing at a ZN/P value of about 32 (corresponding to a load factor of 500). At greater load factors some babbitt wear probably is occurring, with a corresponding gradual decrease in the true bearing clearance. Friction data for this bearing, as given in Fig. 11, thus probably are not plotted with true clearance and load factors at load factor values greater than about 500.

If it is assumed that the limiting value of h_o, corresponding to beginning of oil film breakdown, first is reached at a load factor of 500 as indicated by Fig. 9, then a corresponding value of h_o/c of 0.0048 is obtained from the theoretical curve of Fig. 11. With the given bearing clearance, a value of about 0.0002 in. again is computed for h_o, in agreement with the limiting minimum film thickness value previously found for the bearings with smaller clearance.

BEARING WITH 0.250 IN. RADIAL CLEARANCE

From the assumption that the same value of limiting minimum film thickness (about 0.0002 in.) estimated for the small clearance bearings also applies to the bearing with 0.250 in. clearance, it is found from the theoretical h_o/c curve of Fig. 11 that this limiting value will occur at a load factor of about 3000, at which point the oil flow factor should be about 0.001 (from Fig. 10).

As shown by Fig. 10, oil flow measurements which were obtained at load factor values less than about 3000 are in good agreement with theory, while those at greater load factors show less satisfactory agreement. Referring again to Fig. 11, it is seen that all of the measured friction data are obtained at greater "apparent" load factors (based on 0.250 in. clearance) than 3000. This condition suggests that all friction data obtained with this bearing were secured under a transient clearance condition with continuous babbitt wear. As the true clearance and load factor are not known if such a condition exists, all of the friction data, and that portion of the oil flow data obtained at load factors greater than 3000, cannot be properly correlated with theory.

It is shown, however, for that portion of the oil flow data obtained at load factors less than 3000, where it is indicated that the initial clearance value is unaffected, the results of test with the large clearance bearing is in agreement with the theory, based on oil film cavitation.

CONCLUSIONS

It has been shown that measured friction and oil flow data are in reasonable agreement with values computed from theory of partial journal bearings as based upon existence of oil film cavitation. It is concluded that the cavitation theory can be applied with suitable accuracy to practical problems involving partial bearings with large or small clearance, if the bearing is operating with fluid film lubrication. The limiting value of minimum oil film thickness, associated with beginning of oil film breakdown, is found to be about 0.0002 in. for the railroad journal bearing.

Possible serious operating difficulties associated with early oil film breakdown in railroad bearings having large clearance have been demonstrated. It has been shown that the extensive run-in period required for such babbitt bearings with large initial clearance may be reduced or eliminated by closely fitting the bearing to the journal. This can be accomplished by providing an initial radial clearance of about 0.003 in. over a minimum seating width of about 2 inches on the 6 in. diameter railroad bearing.

BIBLIOGRAPHY

1. J. C. Lee, "Analysis of Partial Journal Bearings Under Steady Loads," Paper No. 55-Lub-1, presented at the Second Annual ASME-ASLE Lubrication Conference, Indianapolis, Ind., October 10-12, 1955.
2. H. A. S. Howarth, "A Graphical Study of Journal Lubrication (Part III)," *Trans. ASME,* Volume XLVII, (1925), pp. 1073-1093.

Patent Abstracts

(Compiled by Ann Burchick, Aluminum Company of America.)

Soluble Oil, Patent No. 2,770,595 (J. L. Jezl, assignor to Sun Oil Co.) A soluble oil composition comprising: mineral lubricating oil having S. U. viscosity at 100°F. within the range from 40 to 120 seconds; alkali metal soap of petroleum mahogany sulfonic acids; alkali metal soap of petroleum naphthenic acids; a saponified oxidation product mixture obtained by partially oxidizing petroleum foots oil in liquid phase at a temperature in the range from 260 to 320°F. and a pressure from atmospheric to 100 psig in the presence of a metallic oxidation catalyst until the saponification number of the oxidation product mixture is within the range from 60 to 120 mg. of KOH per gram, and saponifying said oxidation product mixture with an alkali metal basic compound; 2.75 to 5.0 volume percent of water; and 1.25 to 3.0 volume percent of cyclohexanol; said soluble oil having sulfonate saponification number equivalent within the approximate range from 3 to 10 and carboxylate saponification number equivalent within the approximate range from 10 to 20, approximately half of said carboxylate saponification number equivalent being supplied by said oxidation product mixture.

Soluble Oil, Patent No. 2,770,597 (J. L. Jezl, assignor to Sun Oil Co.) A soluble oil composition comprising: mineral lubricating oil; alkali metal soap of petroleum mahogany sulfonic acids; alkali metal soap of petroleum naphthenic acids; a saponified oxidation product mixture obtained by partially oxidizing petroleum foots oil in liquid phase at a temperature in the range from 250 to 320°F. and a pressure from

(Continued on p. 556)

Apparent Adsorption Isotherms of Oleic Acid From Hydrocarbons as Obtained from Coefficient Of Friction Measurements

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Arthur A. Anderson, General Mills, Inc. Mechanical Division, Minneapolis, Minn.*

Boundary friction as a function of temperature of steel sliding on lead-base babbitt lubricated with various hydrocarbon solutions of surfactants was investigated with the friction pendulum. Certain regular relationships between the coefficient of friction versus concentration isotherms were observed which resembled simple monolayer adsorption. A Langmuir treatment was applied expressing the surface coverage in terms of coefficients of friction of the carrier fluid and the given blend of surfactant. A number of dilute solutions of oleic acid in hydrocarbon were studied at 60, 80, 100, 120 and 140°C, and the experimental friction-concentration data were found to fit monolayer-type isotherms in a satisfactory manner. Implications and limitations of the treatment are discussed and application to potential problems given.

The relation between adsorption and boundary lubrication has been of interest to a number of workers. Hardy[1] demonstrated that extremely thin films of polar compounds may function effectively as lubricants at room temperature. This work was confirmed by Langmuir[2], among others using the Langmuir-Blodgett technique. Many of the conclusions concerning the influence of temperature on boundary friction for pure fatty acids or their hydrocarbon solutions involve indirect experimental evidence.

Bowden and Tabor describe[3] investigations showing characteristic transition temperatures for given fatty acids, above which smooth frictional behavior is no longer attained. For noble or unreactive mating metals, the transition temperature is believed by these workers to be related to the softening point of the solid lubricant. For reactive metals, the transition temperature was postulated to be related to the softening point of the corresponding soap.

Similar results were obtained with solutions of fatty acids in hydrocarbons by Shooter[4] and Gregory[5], but with lower transition temperatures than for the corresponding solids. Frewing[6], from transition temperature studies, has evolved a treatment relating these temperatures with the fraction of the surface covered by the adsorbed film. Brophy and Zisman[7] have used a similar treatment to relate the minimum temperature at which wetting occurs for amphipathic liquids on solids. Greenhill[8] studied both the adsorption of polar compounds on solids and friction transition temperatures. Correlation was obtained between ease of adsorption and coefficient of friction.

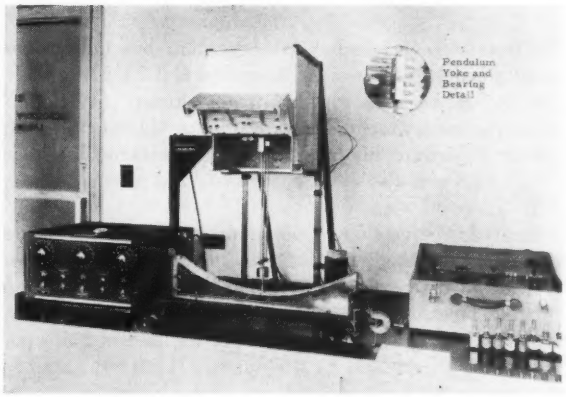

Fig. 1. Friction pendulum.

Unfortunately, transition temperature values are related to the degree of elastic freedom of the constraining member in the stick-slip apparatus which was used in most of these studies. Also, the coefficient of friction has normally been considered to remain constant below the transition range or to rise slightly.

The experiments described in this paper demonstrate the lubricating behavior of dilute solutions of oleic acid as a function of temperature, and an attempt is made to relate this behavior to the adsorption of a monomolecular film.

EXPERIMENTAL

The apparatus used to measure coefficients of boundary friction at various temperatures was the friction pendulum developed during this program and described in a previous paper[9]. It is based on instruments discussed by Barker[10] and Kyropolous and Shobert[11]. A view of the apparatus is shown in Figure 1. An 0.5 inch diameter lapped and polished steel journal is mounted in the yoke of the pendulum assembly and the unit is suspended on a babbitt bearing consisting of two polished, plane, bearing blocks mounted at right angles to each other. Pendulum motion is initiated by a magnetic release and the maximum amplitude for each oscillation is recorded on waxed indicator paper by means of an induction coil system actuated by a key. A furnace and appropriate controls are used for the elevated temperature studies.

*Work performed at the Armour Research Foundation and sponsored by the Association of American Railroads.

Paper Presented at 12th Annual ASLE Meeting, April 15, 1957.

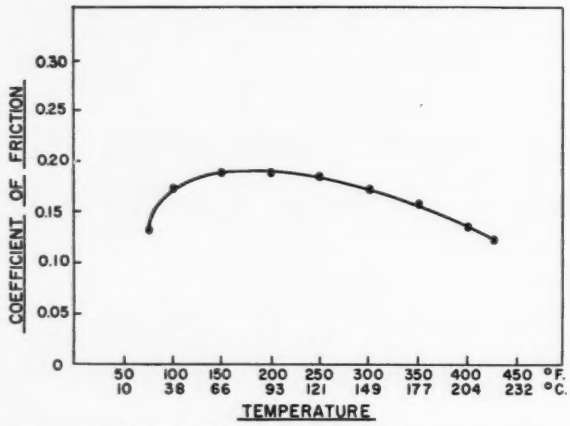

Fig. 2. Coefficient of friction vs. temperature for pure, paraffinic oil.

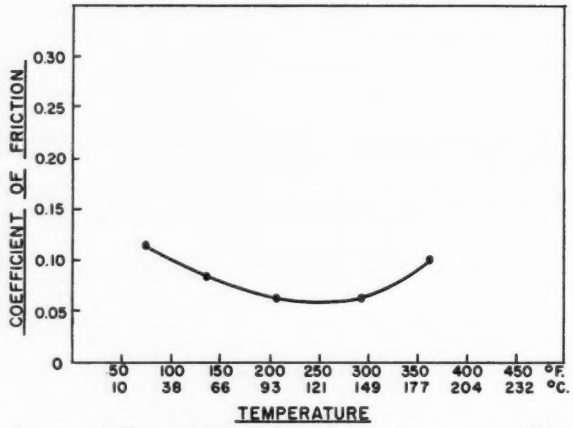

Fig. 3. Coefficient of friction vs. temperature for one percent Oleic Acid in paraffinic carrier fluid.

All tests were conducted in a constant humidity room maintained at 40% relative humidity and 75°F.

It has been shown that the coefficient of friction under boundary conditions is a linear function of the decrement in amplitude during each oscillation. Thus:

$$f = \frac{L \cos\theta \ (A_o - A_n)}{4rn} \qquad [1]$$

where f is the coefficient of boundary friction, L is the distance from the center of gravity to the point of suspension of the pendulum, θ is half the angle between the bearing faces, r is the radius of the journal, and A_o and A_n are the amplitudes in radians of the first and nth periods, respectively.

RESULTS AND DISCUSSIONS

The change in the coefficient of friction as a function of temperature for the steel-babbitt metal system lubricated with a pure, paraffinic oil is shown in Figure 2. The gradual increase in coefficient of friction from room temperature to 95°C may be considered as typical of a physical desorption phenomenon. Above 95°C the decrease in f is considered to be associated with the oxidation of lubricant leading to transient formation of acids. These curves are reversible in nature.

A series of dilute solutions of oleic acid in the paraffinic carrier fluid was prepared and changes in coefficient of friction as a function of temperature were obtained for these various concentrations. A representative friction-temperature curve is shown in Figure 3 for a one percent oleic acid blend. A decrease in coefficient of friction as the temperature is increased is observed until a temperature of approximately 120°C is attained. Above this value, the coefficient of friction rises rapidly as the temperature is increased. The experimental results for the various concentrations are compiled in Table I. Two complete friction-temperature runs were made at each concentration.

In cases of severe disagreement, an additional determination was made. The range of values determined from the several experiments is indicated in the table. The resultant friction isotherms obtained from this data are presented in Figure 4. The decrease in the friction coefficient has been plotted against concentration, where f_c is the coefficient of friction of a blend containing c weight per cent of oleic acid and f_o is the coefficient of friction of the base oil alone. Inspection of Figure 4 reveals that maximum reduction of the coefficient of friction of the lubricated steel-babbitt has occurred at about two percent oleic acid concentration, throughout the temperature range studied.

The regular behavior of the friction-concentration isotherms suggested the possibility of treating the data by classical kinetics, resulting in the following treatment after Langmuir[12].

For dilute solutions of surfactant, it is postulated that monolayer adsorption is in effect. Thus, at equilibrium at a given temperature, the rate of adsorption is given by the expression:

$$k_{ads} = (1 - \theta) \ ca \qquad [2]$$

where c is the concentration of the surfactant, θ is the

TABLE I Experimental Results — Effect of Temperature on Friction Coefficient at Various Concentrations

Concentration (weight %)	Temp. °C	Coefficient of Friction 60	80	100	120	140
0		.191	.191	.191	.188	.180
0.1		.146	.146	.147	.149	.149
0.3		.124	.120	.116	.119	.116-.124
0.5		.104	.097	.092-.094	.096	.101-.104
0.75		.090-.100	.077-.094	.066-.095	.060-.103	.061-.117
1.0		.088	.071-.084	.065-.085	.064-.090	.065-.094
1.5		.085-.091	.075-.089	.070-.089	.075-.090	.087-.102
2.0		.081-.083	.070-.080	.054-.072	.051-.079	.054-.093
5.0		.076	.066	.059	.051	.047
10.0		.064	.056	.052	.045	.039
25.0		.061	.050	.049	.040	.034

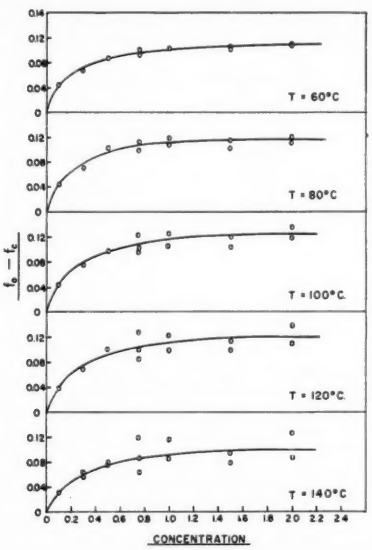

Fig. 4. Reduction in friction coefficient of carrier fluid by Oleic Acid blend vs. concentration under isothermal conditions.

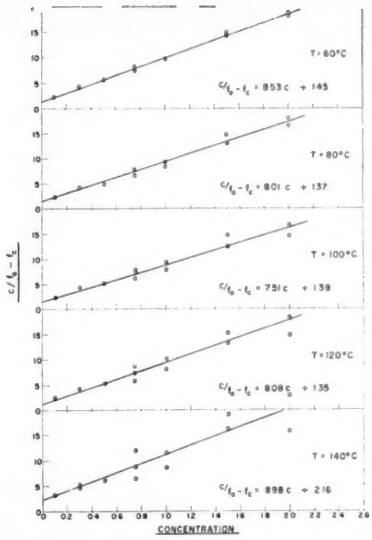

Fig. 5. Fit of experimental data to a monolayer-type isotherm.

fraction of the metal surface upon which surfactant has been adsorbed, and a is a constant.

The rate of desorption is given by:

$$k_{des} = \theta a' \qquad [3]$$

where a' is a constant. Since equilibrium and isothermal conditions are invoked, the rate of adsorption is equal to the rate of desorption; hence:

$$\frac{\theta}{(1-\theta)c} = \frac{a}{a'} = J \qquad [4]$$

where J is a constant.

Because friction phenomena are surface effects, it is proposed that it is possible to relate θ with f in a linear manner such that the following relationship holds:

$$\frac{df}{dc} = -k\frac{d\theta}{dc} \qquad [5]$$

where k is a constant. Upon integration:

$$f = -k\theta + A \qquad [6]$$

where A is the constant of integration. The boundary conditions are chosen such that when θ is equal to zero, the coefficient of friction is that of the pure paraffin oil, f_o. Thus, at a given temperature, the fraction of the surface covered by the adsorbed film may be related to the coefficient of friction of pure base oil and of the blend containing c weight percent of oleic acid as follows:

$$\theta_c = \frac{f_o - f_c}{k} \qquad [7]$$

Equation [4] may be written in the following form:

$$\frac{C}{\theta} = \frac{1}{J} + c \qquad [8]$$

Substituting [7] into [8], the following expression is obtained:

$$\frac{c}{f_o - f_c} = \frac{1}{kJ} + \frac{c}{k} \qquad [9]$$

Thus, $c/(f_o - f_c)$ should be linear with respect to c Figure 5 shows the agreement of the experimental data with the postulated equation.

Values of the Langmuir constants k and J calculated from the curves are summarized in Table II. The constant k is equal to maximum friction reduction or:

$$k = f_o - f_c \qquad [10]$$
$$\text{(minimum)}$$

In general, the minimum coefficient of friction calculated from the slope of $c/(f_o - f_c)$ vs c agrees reasonably well with the observed values at 2-5 percent concentration.

Values of the constant J may be set equal to the reciprocal of the concentration at which half the maximum reduction in friction is obtained. Although the concentrations selected for the friction experiments did not permit the pinpointing of this value, the calculated concentrations do fall within the correct experimentally observed range at each temperature.

It is believed that the frictional behavior exhibited by oleic-acid solutions may be explained by a combination physical and chemical adsorbtion process. As the temperature is increased gradually above room temperature, a greater fraction of the adsorbed oleic acid molecules, bound by weak physical adsorption forces, absorb sufficient thermal energy to react with the metal atoms on the surface to form a close-packed soap monolayer. The formation of a two-dimensional soap (monolayer) is postulated on the basis of the results in Figure 5. The soap formed in place has a close-packed structure accounting for the low coefficient of friction. At temperatures in excess of approximately 120°C, thermal agitation of chemisorbed molecules, as well as the increased solubility of both the soap and the oleic acid, results in disorientation and destruction of the adsorbed layers with accompanying increase in friction. The proposed combination physical and chemical adsorption process could also account for the constancy of J up to 120°C.

It is interesting to observe that several experiments carried out at 10 and 25 percent oleic acid concentrations resulted in friction data which did not correspond to a Langmuir isotherm. It is possible that at high oleic acid concentrations, multilayer formation occurs. White[13] has found that the shear resistance or coefficient of friction of films of various soaps under high pressure reveal lower values at 100° than at 27°C. Above 100°C films no longer separate the surfaces. An alternate explanation for the nonconformity of the high concentration solutions to the Langmuir isotherm is that close-packing of the adsorbed molecules results in appreciable attractive forces between methylene groups in adjacent chains. The Langmuir equation, however, requires that no lateral cohesion forces be present[7].

A treatment of friction data by the Langmuir isotherm approach is similar to the same correspondence observed by Uhlig and Geary[14] and Hackeman and Sudbury[15] who studied the passivating effect of ionic and polar organic compounds adsorbed on metals. Monolayer formation was also found in their experiments.

SUMMARY

The foregoing treatment may be of value in the rapid determination of the relative merits of various surfactants for reducing the coefficient of boundary friction. It

TABLE II Comparison of Theoretical and Experimental Values

Calculated		Minimum f_c	Experimental		
Temp. °C	$f_{c(\min.)} = f_o - k$	Conc. 2%	5%	10%	25%
60	0.074	0.081	0.076	0.064	0.061
80	0.066	0.075	0.066	0.056	0.050
100	0.058	0.063	0.059	0.052	0.049
120	0.064	0.065	0.051	0.045	0.040
140	0.069	0.074	0.047	0.039	0.034

Concentration Yielding ½ Maximum Reduction in f

Temp. °C	Calculated $C\ \frac{1}{2} = \frac{1}{J}$	Experimental
60	0.17	Between 0.1 and 0.3
80	0.17	Between 0.1 and 0.3
100	0.18	Between 0.1 and 0.3
120	0.17	Between 0.1 and 0.3
140	0.24	Between 0.1 and 0.3

serves to further verify the concept that solutions of boundary lubricants reduce friction by formation of monomolecular films through adsorption and to predict that friction-temperature relations for surfactants are not necessarily monotonic functions. Further work is, of course, necessary to extend these findings to other surfactants and different mating metals.

BIBLIOGRAPHY

1. Hardy, "Collected Works". Cambridge University Press (1936).
2. Langmuir. *Trans, Faraday Soc. 15:* 68 (1920).
3. Bowden and Tabor. "Friction and Lubrication of Solids." Oxford University Press (1955).
4. Shooter. Brit. J. *Appl. Phys.* (Supl.) *1:* 49 (1951).
5. Gregory. C.S.I.R. (Austral.) Tribophysics Div. Rep. A, *74:* (1943).
6. Frewing. *Proc. Roy. Soc. A, 182:* 270 (1944).
7. Brophy and Zisman. *Ann. N.Y. Acad. Sci. 53:* 836 (1951).
8. Greenhill. *Trans. Faraday Soc. 45:* 625, 631 (1949).
9. Miller and Anderson. "Investigation of Oil Additives". ASLE 11th Annual Meeting, 1956.
10. Barker. *A.S.T.M. Bull. 139:* 33 (1946).
11. Kyropolous and Shobert. *Rev. Sci. Instru. 8:* 151 (1937).
12. Langmuir. *J. Am. Chem. Soc. 40:* 1361 (1918).
13. White. *Lubr. Engr. 10:* 340 (1954).
14. Uhlig and Geary. *J. Electrochem. Soc. 101:* 215 (1954).
15. Hackeman and Sudbury. *J. Electrochem. Soc. 97:*109 (1950).

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Patent Abstracts

(Continued from p. 552)

atmospheric to 100 psig in the presence of a metallic oxidation catalyst until the saponification number of the oxidation product mixture is within the range from 60 to 120 mg. of KOH per gram, and saponifying said oxidation product mixture with an alkali metal basic compound; 2.25 to 5.0 volume percent of water; and 0.75 to 3.0 volume percent of an organic compound selected from the group consisting of dihydroxy alkane having 8 to 10 carbon atoms inclusive; said soluble oil having sulfonate saponification number equivalent within the approximate range from 3 to 10 mg. of KOH per gram and carboxylate saponification number equivalent within the approximate range from 10 to 20 mg. of KOH per gram, said saponified oxidation product mixture providing carboxylate saponification number equivalent within the approximate range from 5 to 10 mg. of KOH per gram and said alkali metal soap of petroleum naphthenic acids providing carboxylate saponification number equivalent within the approximate range from 5 to 10 mg. of KOH per gram.

Manufacture of Odorless & Odor-Stable Mineral Oil, Patent No. 2,772,316 (S. Schneider, assignor to Esso Research & Engineering Co.) Process of manufacturing substantially odorless and odor-stable mineral oils which comprises alkylating a low-boiling isoparaffin hydrocarbon with a low-boiling olefin hydrocarbon, fractionating the resulting alkylate into a plurality of fractions including a fraction boiling within the range of about 330 to 550°F., acid-treating said fraction with concentrated sulfuric acid, neutralizing the acid-treated fraction with an alkali, and washing the neutralized fraction with an aqueous aliphatic alcohol.

Lubrication Abstracts

(Continued from p. 542)

As it is not possible to build into wire-rope the lubrication requirements for its service life, supplementary applications are necessary. In the past heavy-bodied lubricants were recommended which coated external parts but failed to penetrate between inner strands. Nowadays wire-rope manufacturers recommend frequent applications of a light-bodied lubricant to protect against internal corrosion and minimize internal friction. Several spray and drip-type applicators are discussed. (*Abstractor: E. S. Reynolds*)

"Titanium Extrusions." A. M. Sabroff (Batelle Memorial Institute, Columbus, Ohio) and P. D. Frost, *Modern Metals, v.* 13, *no.* 5, 1957, 50-58; *no.* 6, 1957, 52-64.

A comprehensive survey of current industrial practice in hot extrusion of titanium is presented. Part I considers the problem of lubrication; Part II deals with the preparation of metal, die design and related practices. Two basic lubricants are used: (1) greases which contain solid-film lubricants, and (2) glass. Copper coatings may also be used. Greases give high quality finish and close dimensional tolerances. Most successful formulations contain calcium soap or bentone greases with 25% of graphite. Greases containing 15% of MoS_2 and 5% mica are also effective. Glass gives far better tool life because of its insulating characteristics. It also affords better protection to the mandrel during piercing. Fabrication of long tubes with a good over-all surface requires the use of a glass lubricant. (*Abstractor: W. J. Wojtowicz*)

Cutting Fluid Performance

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A test method is described for the comparative evaluation of cutting fluids under typical commercial conditions. Measurements of tool-wear rate, work surface finish and cutting temperatures are used in the evaluation. Insufficiency of a single criterion of quality is illustrated and use of composite measurements is stressed. Statistical interpretation of data is discussed.

Transfer of radioactive material from a cutting tool to the chips produced in facing steel tubing in a lathe is used as a measure of tool-wear rate. Use of low-activity tools with sensitive counting equipment simplifies personnel protection against radiation hazards.

Techniques are described for obtaining surface finish measurements on surfaces representing average running rather than stopping conditions.

Procedures are outlined for obtaining cutting temperatures while providing adequate chip breakage for wear measurements. Comparative results for compounded and mineral oils in the machining of A.I.S.I. Type 1015, 1045, 4130 and 304 steels are reported.

A reliable laboratory method of evaluating cutting fluids is desirable both as a basis for the selection of oils for commercial machining operations and as an aid in the development of new formulations. The action of a cutting fluid is complex, and its composition, common physical properties and special properties, such as wetting ability, lubricity, etc., do not provide accurate criteria of effectiveness under machining conditions. Therefore, evaluation of a cutting fluid should involve actual metal cutting tests.

METAL CUTTING MECHANISM

During machining, an unstable irregular wedge-shaped layer of chip material, called the built-up edge, is pressure welded to the face of the tool. Separation of chip from work occurs at the built-up edge as shown in Figure 1. [1,2,3,4] The chip passing over the tool face scours or scrapes off tool material and, in time, forms a crater behind the edge. At the same time, the work, using fragments of the built-up edge as an abrasive, scours the flank of the tool. Whether flank wear or cratering predominates is determined by conditions of operation.

Passage of the chip over the tool is retarded by friction between tool and chip. Thickness of the chip is influenced by the magnitude of this retarding force. A low coefficient of friction produces long thin chips; a high coefficient gives short thick chips. The amount of chip deformation is measured by the chip-length ratio which is the length of chip divided by the original length of metal in the chip. This is in effect the ratio of the depth-of-cut to the thickness of the chip.[1,3,4]

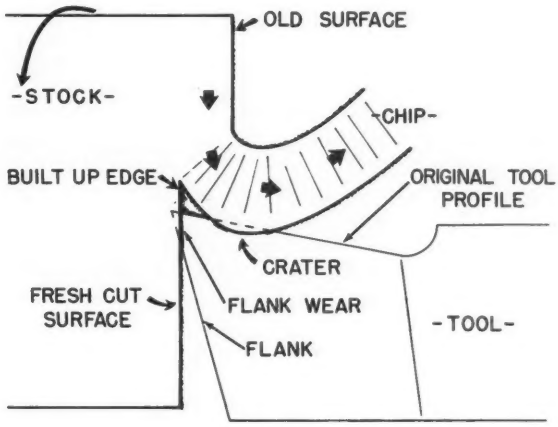

Fig. 1. Mechanisms of metal cutting and tool wear.

METHODS OF EVALUATING CUTTING FLUID PERFORMANCE

Cutting fluids affect the machining mechanism by cooling, lubricating, and assisting in chip removal. Each of the several aspects of the machining operation has been used as a means of evaluating the effectiveness of the fluid. The more common methods are: (1) measurement of tool-wear rate, (2) determination of chip-length ratio and coefficient of friction, (3) determination of cutting temperature, and (4) measurement of surface finish.

Direct microscopic measurement of flank wear on the tool is successful only when this form of wear predominates. It fails where cratering is the cause of failure or where tool life is limited by excessive temperatures or welding of stock to tool. This method consumes excessive amounts of stock in making a complete test.

Tool wear may also be measured by operating under abnormally severe conditions which destroy the tool in a reasonable test time (destruction test). Because test conditions are severe, extensive extrapolation is necessary to extend the results to commercial conditions. Considerable error may thus be introduced. A more serious defect in this test is the possible large difference in fluid performance under severe and normal cutting conditions. This procedure also requires cutting of considerable stock.

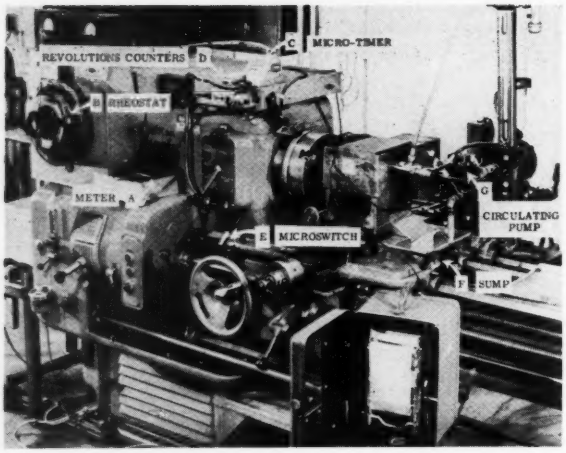

Fig. 2. Test Equipment.

The amount of tool material removed by a small quantity of chips cut under commercial machining conditions is too small to measure by ordinary techniques such as weight loss. However, radioactive detection methods provide necessary sensitivity. Merchant, *et.al.*[5] have found the wear particles from the tool to be transferred predominantly to the chips (about 95%), and thus by monitoring the chips, one can measure total tool wear. This appears to be the best available method for determining tool wear because of the following advantages:

1. Very small amounts of wear may be determined accurately.
2. Metal cutting tests may be conducted under conditions similar to those used in industry.
3. Stock is consumed in very small amounts with correspondingly small machining times.

Coefficient of friction between chip and tool may be calculated from measured values of the thrust, cutting force, and cutting geometry. Chip-length ratio also provides measurement of the friction between chip and tool. Both criteria are indices of the lubricating ability of the fluid. However, they have been found to have too small a range of values at commercial cutting conditions to be useful in cataloging cutting fluid performance. Neither has been found useful in estimating tool life.

Surface finish of the cut stock is a measure of the quality of the machining operation. It is not satisfactory as the sole criterion of cutting fluid effectiveness because of its sensitivity to properties of the stock, the speed and feed, and the tool geometry.

Temperature at the interface between the tool and the work-piece correlates roughly with tool-wear rate. Like surface finish it is sensitive to cutting conditions, hence, it is an inadequate criterion alone.

While neither surface finish nor cutting temperature are adequate criteria alone, they provide valuable supplementary information for the proper interpretation of tool-wear measurements. The method of using these additional criteria will be illustrated in the description of the test procedure.

EXPERIMENTAL

Measurement of Tool Wear by Radioactive Means

The advantages of radioactive methods over other methods of tool-wear determination justify the rather elaborate experimental apparatus and procedure required. In this work a lathe was used as the basic equipment. However, the general procedure described can be adapted to other machine tools such as a milling machine.

Apparatus:

The principal components of the test equipment are:

1. A 16" x 54" lathe with a DC motor drive,
2. A lead box shielding the radioactive tool, and
3. A well-type Geiger tube with a preset counter.

Figure 2 is a photograph of the complete experimental set-up. Cutting speed is indicated on meter A and is controlled by rheostat B. The average speed during cutting is calculated from data supplied by microtimer C and revolution counters D. The timer and counters are electrically operated by microswitch E which is adjusted to close at the start of the cut and open when cutting is completed.

The cutting oil under test is stored in 1½ gallon sump F attached to the carriage and is circulated by pump G at a rate of about 4 gallons per minute.

Procedure:

Orthogonal machining, as illustrated in Figure 3, is conducted on the end of a 1½ inch O.D. by ¼ inch wall tube with a radioactive high-speed-steel tool at the selected and carefully controlled machining condition. Particulars of the cutting geometry, tool chemistry and stock are listed in Table I.

To insure rapid break-up of the chip into relatively uniform segments of a size that will pack in the well-type Geiger counter, both a chip breaker and filled slot in the workpiece are provided. When the slot passes the tool, the chip is broken, and each revolution of the stock produces one chip in the ideal case. Metal of the same or similar chemistry as that of the tube is used for slot fill. The filling of the slot is necessary to prevent shock on the tool.

The chips from the first third of a test run are discarded because they represent transistory cutting conditions wherein the tool is coming up to temperature. Chips from the balance of the run, representing steady state conditions, are used to measure tool wear.

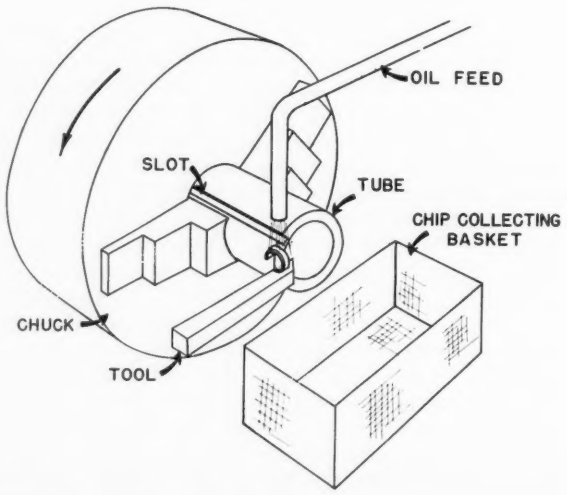

Fig. 3. Orthogonal machining on end of steel tube.

Several measurements of counting rate of a chip sample are made in the well-type Geiger counter. Background rates are measured between sample rates. Both are averaged and the difference is divided by the weight of the chip sample. The result is reported as the tool-wear rate in counts per second per gram of chips—cps/g. A sufficient number of counts are made to insure a counting error of less than 2% as estimated from the confidence limits of the data.

Safety Precautions:

Certain precautions are necessary to insure the safety of personnel. The cutting tool is adequately shielded in use by the lead box on the lathe, and proper storage facilities are provided for tools not in use. The operators are furnished with Keleket pocket dosimeters to check daily radiation dosage and are given blood tests twice a year. Other laboratory personnel are not permitted in the limited area about the lathe. No special precautions are taken in handling chip samples because of the low level of radioactivity.

Surface Finish Measurement

To preserve a cut surface on the end of the tube typical of cutting conditions, the test is abruptly terminated by a rapid withdrawal of the tool (withdrawal covers only a portion of one revolution of the tube). A dial indicator is used to determine the sector of the cut surface of the tube which was produced during test cutting as distinguished from the sloping portion cut during the withdrawal. Only the former is used for surface finish measurement.

A one-inch ring is sawed from the end of the tube and placed in the holder of a mechanical rotating device. This reciprocates the ring over an arc within the bounds of the test surface. The pick-up of a commercial profilometer rests on the cut surface on the end of the tube. Output of the profilometer is fed to an indicating dial and a photoelectric recorder. Surface finish is determined by averages of the trace on the strip chart.

Measurement of Cutting Temperature

Tool-chip temperatures are measured by a method based on the work of Shore[6] in which the interface between the chip and tool form the hot junction of a thermoelectric circuit. The dissimilar metals of tool and workpiece, in contact during machining, provide the thermoelectric indication. Temperature-emf relationships for each combination of metals are obtained by a calibration.

Radiation and strength considerations require the tool steel to be of different chemistry than the tool holder. As a result a parasitic emf is introduced into the thermocouple circuit during machining since electrical insulation of the tool from the tool holder is not practical with the small radioactive cutter. Laboratory calibrations indictate the magnitude of this error to be as follows:

304 steel — +10F
4130 steel — + 5F
1045 steel — +25F
1015 steel — +15F

TABLE I

CUTTING TOOL AND STOCK DATA

A. High Speed Steel Tool

1. Cutting Angles, when mounted in tool holder:

back rake	— 0 deg.
side rake	— 15 deg.
side relief	— 6 deg.
side cutting edge	— 0 deg.

2. Chemistry

C	Si	Mn	S	P	W	Cr	Va	Mo	Co	Fe
0.83	0.26	0.25	0.010	0.025	18.90	4.13	1.93	0.80	8.94	balance

3. Radioactive level
   2 millicuries — Table II
   7 millicuries — All other data
4. Weight — 2 grams
5. Approximate Size — 7/16" x 7/16" x ⅛"

B. Stock

1015 steel tubing — random lengths — 87 to 90 Rockwell B Scale
1045 steel bar stock — hot rolled, shop drilled and turned to tubing — 88 to 91 Rockwell B Scale
304 steel tubing — random lengths
4130 steel tubing — random lengths

A similar effect has been reported by Trigger[7] for carbide tools. These corrections were not made to the data since (1) their magnitude is less than the measuring error and (2) they have no effect on the relative difference between oils.

The tool holder is insulated from the lathe with a thin sheet of varnished cambric and the chip-breaker is insulated from both tool and tool holder with sheet mica.

The workpiece is insulated from the chuck jaws with a thin sheet of varnished cambric (Figure 4). Acrylic plastic sheet insulates the chuck jaws from the dog clamped to the workpiece. The dog-tail is electrically insulated from the chuck by a thin-wall fibre tube. The use of a dog prevents possible slipping of the tube in the chuck with consequent tearing of the varnished cambric. A plastic collar is used to center the end of the work in the spindle to prevent electrical contact.

Connection to the high-speed potentiometer recorder shown in the foreground of Figure 2 is made from the tool holder and from a spring-loaded brush in contact with the rotating workpiece. This circuitry assumes the brush and tool holder are the cold junction, both at room temperature.

DISCUSSION

The need for several criteria for evaluating cutting fluids is illustrated by tests made with a plain mineral oil and a commercial compound oil of recognized merit. From these data, which are summarized in Table II, it is seen that the relative effect of the two oils on tool-wear rate is dependent upon cutting conditions. Surface finish and temperature data, however, are consistent in pointing up the poorer quality of the mineral oil. This need of criteria to supplement wear rates can be explained by consideration of the action of the cutting fluids.

Compound oils achieve better cutting performance and smoother surface finishes through the formation of boundary lubricants. Extreme Pressure (E.P.) agents, usually oil-soluble compounds containing chlorine or sulfur, react with the nascent metal surfaces to form an "easily-sheared" surface layer. While ordinary boundary lubricants interpose some kind of thin film between rub-

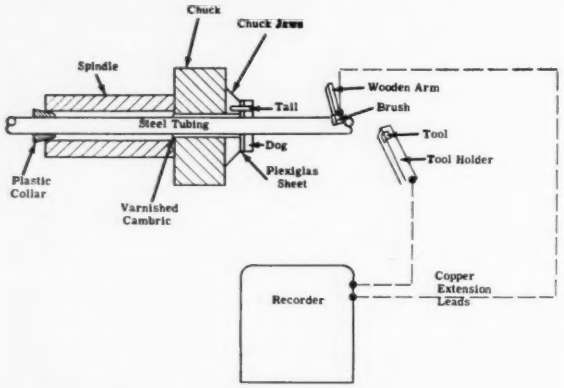

Fig. 4. Measurement of tool-chip interface temperature.

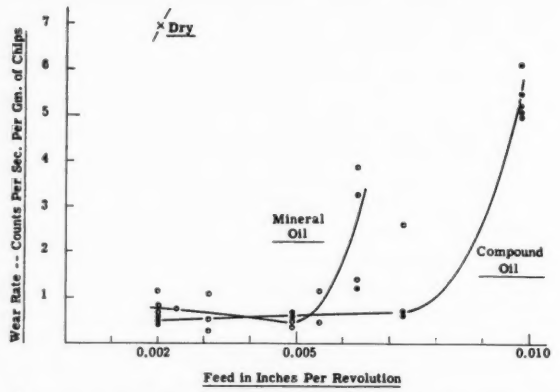

Fig. 5. Effect of cutting fluid on tool wear rate and temperature.

bing surfaces, and thus protect the surfaces against attrition, E. P. agents by their chemical action destroy the metal surface of both tool and work.

Tool wear, therefore, involves a balance between chemical attack, abrasion, and welding when the work is flooded with a compound oil. Under mild conditions, chemical attack appears to outweigh abrasion and welding and, in this manner, results in higher tool-wear rates with compound oil floods. Under more severe conditions, welding of cut metal to the tool face governs and E. P. agents are essential. Beaubien and Cattaneo[8] report similar instances where mineral oils give greater tool life than compound oils.

Tests made with 1045 steel involve essentially the same physical set-up used for 1015 steel. Since 1045 chips are self breaking, the chip breaking slot in the tube is not provided. These data are presented in Figure 5 and represent some 53 tests encompassing two oils and dry cutting for a range of feeds at constant cutting speeds.

Dry cutting is possible only at the lowest feed and both wear rate and cutting temperature are prohibitively high. Mineral oil cutting temperatures are higher than compound oil temperatures for all cutting conditions. Presumably the reduction of friction at the tool-chip interface effected by the E. P. agents in compound oil is responsible by reducing shear work as described by Beaubien and Cattaneo.[8]

The wear rate data for the oils indicate pronounced differences between the oils. Once again a point exists wherein mineral oil wear rates are less than compound oil wear rates. However, the trend of the data points to better performance with compound oil.

The cutting geometry, which was unchanged from previous tests with 1015 steel, is not optimum for 1045 steel. As a result surface finishes are consistently poor and are omitted in this case since they do not provide a useable measure of oil quaiity.

Figure 6 is a plot of all the data in Figure 5, plus tests conducted at 80, 90 and 100 surface feet per minute, and indicates temperature to be a good correlating criterion. Temperatures below 650°F were not observed, possibly because the work was not carried far enough or the measuring technique was not sufficiently precise. Efforts were made to obtain lower temperatures by reducing the duty but were limited by the physical set-up. It appears that there is a minimum value which is associated with the minimum energy dissipated by resistance to shear in the plane where the chip separates from the stock. Below 800°F lower tool wear rates were observed with compound oil than with mineral oil or dry cutting. At temperatures of about 900°F the lowest tool wear rates were obtained with mineral oil floods. Above 1050°F the curves appear to blend and tool wear rate appears to be a function of temperature alone. The E. P. agents present in this particular compound oil apparently lose effectiveness above this temperature and the curve degenerates into a simple cooling curve.

The studies of 1015 and 1045 steels show differences in oil performance. Therefore, complete evaluation of an oil must include steel types as a variable. To provide representative conditions, 304 and 4130 steel tubing are used as test metals in addition to 1015 and 1045. Tool chatter is a problem in both 304 and 4130 steels. Since

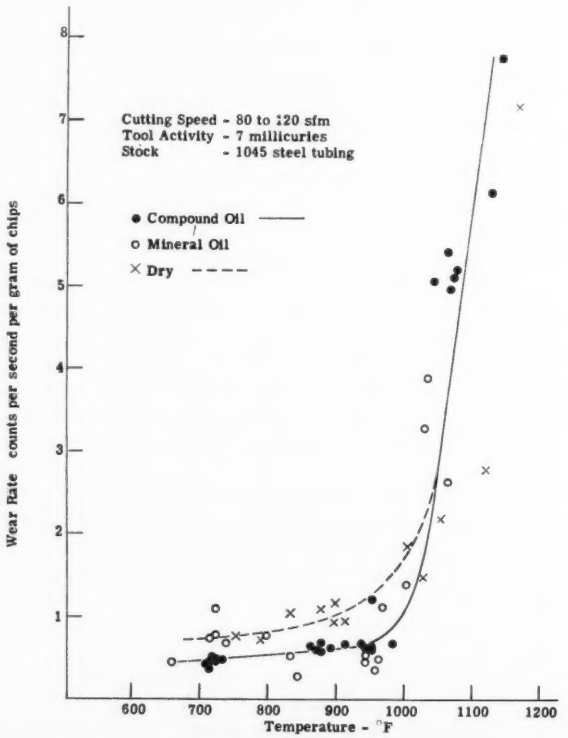

Fig. 6. Correlation of tool wear rate to I-chip interface temperature.

it is impractical to increase tool rigidity, duty is reduced by machining a thinner (⅛ inch) wall tube. Surface finish measurements are not practical with this thin wall tube so only wear rate and temperatures are determined.

In addition to the several steels and machining conditions, changes in tool geometry because of wear may be an additional source of variation. Absolute measurements of the performance of a cutting fluid thus may be subject to considerable error. More accurate evaluations of quality of a test oil are possible by simultaneous comparison with the performance of a reference oil whose behavior under industrial conditions has been established. Even with this comparison technique the use of statistical procedures is desirable to insure proper design of experiment and interpretation of the results.

Comparisons are made with four new tool edges (four cutting edges on one tool blank). One tool edge is assigned to each steel, and one run is made at each cutting condition — oil combination. After both oils are tested at all 10 conditions (for a total of 20 tests), replicate runs are made with a different tool assignment for each steel. Tool-stock combinations and test order are selected randomly by drawing lots.

Results for the evaluation of an experimental oil formulation are shown in Table III. These raw data are interpreted by analysis of variance.[9] The resulting "F" values are tested for significance using the Fisher ratio test at 95 and 99 per cent confidence levels. (At 95 per cent confidence there exists 19 chances out of 20 that the effect could not take place in a system where only chance events are occurring. Similarly, 99 per cent confidence indicates that there are 99 chances out of 100 that the effect is real.) Table IV summarizes the significance of the effects of oil, cutting conditions, and interactions on wear rate, temperature, and surface finish. In order that possible bias resulting from the wide range of wear rates may be detected, logarithms of wear rate are included. This permits comparison of ratios rather than absolute magnitudes.

From Table IV it is seen that differences between the oils on an over-all basis (all steels) are not mathematically significant at the confidence levels selected. However, the significance of the interaction between cutting conditions and oils means that some operating conditions produce different effects. Difference between oils is further suggested by the mathematical significance of the effect of oil type on logarithm of wear rate.

Extension of the analysis to individual steels indicates 1015 to be the source of differences between oils. Since F values for both oil and interaction are significant, the difference between oils occurs principally in one range of cutting conditions. Reference to Table III shows this difference to occur at the highest feeds. In this range the

TABLE II

WEAR RATE, SURFACE FINISH AND TEMPERATURE DATA FOR MINERAL AND COMPOUND OIL

	Cutting Conditions*	
	Light f = 0.005"/rev. s = 120 sfm	Moderate f = 0.015"/rev. s = 120 sfm
A. Wear Rate, cps/g		
mineral oil	0.019 ± 0.011	0.450 ± 0.105
compound oil	0.047 ± 0.006	0.075 ± 0.011
B. Surface Finish, micro-in.		
mineral oil	186 ± 14	346 ± 148
compound oil	107 ± 7	71 ± 10
C. Temperature, F		
mineral oil	740	806
compound oil	714	748

* 2 millicurie tool
1015 steel

TABLE III

WEAR RATE, TEMPERATURE AND SURFACE FINISH DATA FOR THE REFERENCE AND EXPERIMENTAL OILS

	Cutting Conditions			Reference Oil			Experimental Oil		
Steel	Speed	Feed	Depth of Cut	Wear Rate cps/g	Temp. °F	Surface micro-in.	Wear Rate cps/g	Temp. °F	Surface micro-in.
304	50 sfm	0.005"/rev.	0.125 in.	0.053	780	—	0.041	760	—
				0.030	780	—	0.033	790	—
304	75 sfm	0.005"/rev.	0.125 in.	0.156	880	—	0.158	970	—
				0.185	925	—	0.324	970	—
4130	120 sfm	0.002"/rev.	0.125 in.	0.179	762	—	0.154	763	—
				0.102	755	—	0.133	752	—
4130	120 sfm	0.005"/rev.	0.125 in.	0.579	780	—	0.549	780	—
				0.942	779	—	0.783	780	—
1045	120 sfm	0.002"/rev.	0.250 in.	0.444	620		0.414	635	
				0.546	630		0.464	635	
1045	120 sfm	0.005"/rev.	0.250 in.	1.130	870		1.039	880	
				0.635	880		0.847	870	
1015	120 sfm	0.005"/rev.	0.250 in.	0.171	762	80	0.183	770	81
				0.186	750	91	0.169	760	77
1015	120 sfm	0.011"/rev.	0.250 in.	0.109	876	58	0.150	888	65
				0.099	880	54	0.096	872	62
1015	120 sfm	0.015"/rev.	0.250 in.	0.117	940	54	0.233	970	45
				0.092	955	40	0.242	975	53
1015	120 sfm	0.020"/rev.	0.250 in.	0.654	1010	48	1.887	945	300
				0.757	995	42	1.248	915	356

reference oil probably provides lower tool-wear rates by reducing the welding of stock to tool which is likely to occur with this low carbon steel. These conclusions are substantially confirmed by the analysis of both temperature and surface finish data. By this complete analysis, the experimental oil is seen to approach the known high quality of the reference oil. It is inferior only when machining low carbon steel at relatively severe conditions.

The strong effect of cutting conditions on the measured values emphasizes both the need for careful control of test conditions and the necessity of statistical analysis to differentiate oil quality.

CONCLUSIONS

1. Reliance on any single criterion to evaluate a cutting fluid may give erroneous results. The most reliable technique requires the evaluation of wear rate, cutting temperature and surface finish. If this is not possible, at least wear rate and surface finish or wear rate and temperature should be used.

2. A method of comparative oil analysis has been presented which incorporates recognized statistical techniques. Various oil formulations can be easily compared with a recognized standard, making possible a study of the effects of various additives and additive levels.

Permission of the Standard Oil Company (Indiana) for presentation of this paper is acknowledged.

TABLE IV

VARIANCE ANALYSIS OF THE DATA OF TABLE III

	Fisher F Values[1]		
	Cutting Conditions	Oils	Interaction
Wear Rate			
a. all steels	25.1**	4.2	3.2*
b. 304	15.3*	0.6	0.8
c. 4130	27.1**	0.2	0.2
d. 1045	10.8*	Nil	0.2
e. 1015	36.6**	9.7*	6.4*
Logarithm of Wear Rate			
a. all steels	70.4**	5.6*	1.9
b. 304	46.5**	0.2	0.6
c. 4130	59.2**	Nil	0.2
d. 1045	15.8*	Nil	0.4
e. 1015	136 **	25.5**	6.3*
Cutting Temperature			
a. all steels	358 **	1.0	8.9**
b. 304	138 **	5.3	7.2
c. 4130	49 **	Nil	Nil
d. 1045	3,200 **	1.3	1.3
e. 1015	312 **	2.8	15.9**
Surface Roughness			
1015	71.0**	90.9**	88.5**

* Mathematically significant at the 95% confidence level.

** Mathematically significant at the 99% confidence level.

[1] $F = \frac{\text{variable variance}}{\text{error variance}}$, values calculated must exceed those in tables compiled for 95 or 99% confidence to be significant.

BIBLIOGRAPHY

1. *Machining—Theory and Practice*, ASM, Cleveland, Ohio, 1st ed., 1950, p. 5-68.
2. Boston, O. W., *Metal Processing*, John Wiley and Sons, Inc., New York, N. Y., Chapman and Hall Ltd., London, 1st ed., 1941, p. 95-99.
3. Ernst, H. and Merchant, M. E., *Chip Formation, Friction and Finish*, Cincinnati Milling Machine Co., Cincinnati, Ohio, 1st ed., 1941.
4. Shaw, M. C., *Metal Cutting Principles*, M.I.T., Cambridge, Mass., 1st ed., 1951.
5. Merchant, M. E., Ernst, H. and Krabacker, E. J., *Radioactive Cutting Tools for Rapid Tool-Life Testing*, Transactions ASME, v. 75, n 4, 1953, p. 549-59.
6. Shore, H., S. M. Thesis, M.I.T., Cambridge, Mass., 1924.
7. Trigger, K. J., Campbell, R. K. and Chao, B. T., A Tool-Work-Thermocouple Compensating Circuit, Paper No. 56-A90 given at the ASME Annual Meeting November 25-30, 1956, New York.
8. Beaubien, S. J., and Cattaneo, A. G., Role of the Cutting Fluid in Machining Operations, *Lubrication Engineering*, v. 10, n 2, 1954, p. 74-79.
9. K. A. Brownlee, *Industrial Experimentation*, Chemical Publishing Co., Inc., Brooklyn, N. Y., 3rd ed., 1949, p. 51-57.

Section News

DETROIT—ASLE's Detroit Section joins with Wayne State University, Detroit ASME, and industrial representatives to establish a seven-week course in "Cutting Fluids" slated to run from October 5 through November 16. Enrollment expected to reach 100 . . . Chrysler's Duane F. Miller acting as ASLE representative . . . **MILWAUKEE**—First fall meeting's speaker was Dr. Dimitri Kececioglu, assistant to the director of mechanical engineering at Allis-Chalmers Mfg. Co. His subject: "The Role of Cutting Media in the Machining of Metals." . . . **KINGSPORT**—Bruce M. Dunham, technical consultant for Sun Oil Co., spoke on "Compressor Lubrication." . . . **SYRACUSE** — Regular monthly meetings to be held on third Monday of each month—except December. **NORTHERN CALIFORNIA** — "Fretting" was subject of first meeting. Douglas Godfrey's talk was supplemented by color movies . . . **HOUSTON**—Another color film illustrated Texas Company's William Nicholson's talk on "Performance Characteristics, Care and Handling, and General Requirements of Hydraulic Oils." . . . **LOS ANGELES**—First sessions of ASLE co-sponsored lubrication courses at the University of California met. Subjects to date—Introduction to Lubrication, Basic Principles of Lubrication.

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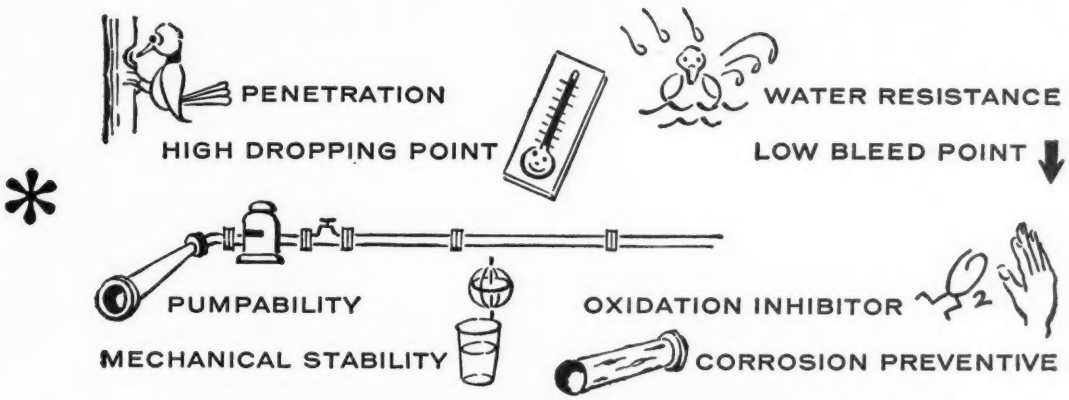

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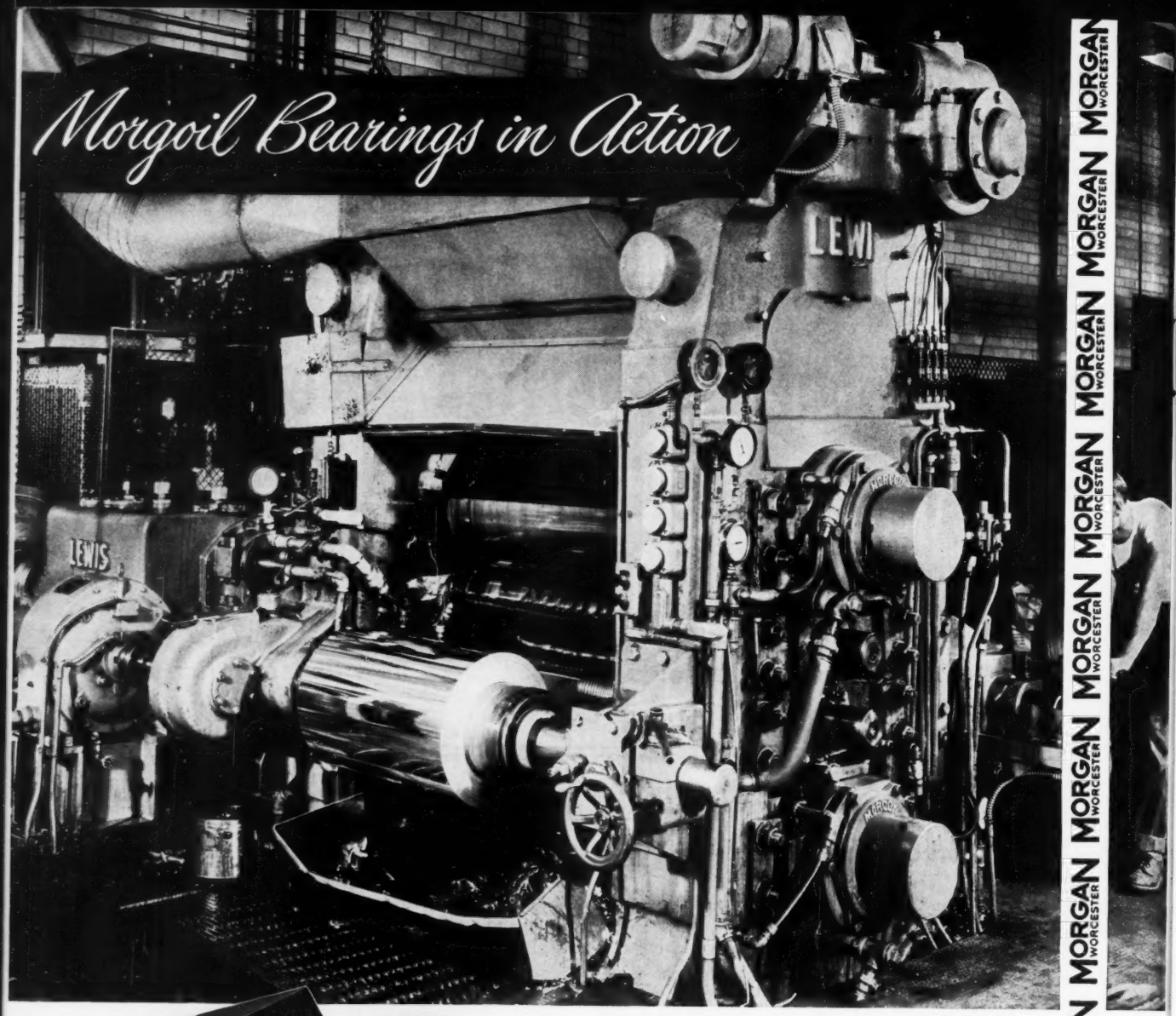

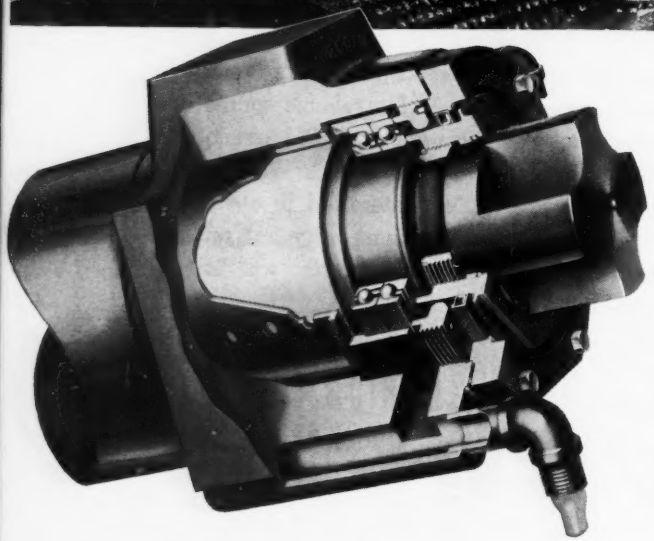

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COMING EVENTS....

October 15—American Institute of Consulting Engineers (Annual Dinner), Waldorf-Astoria Hotel, New York, N. Y.

16-18—Institute of Radio Engineers Canadian Convention, Toronto, Ontario, Canada.

17-18—National Conference on Industrial Hydraulics, Sherman Hotel, Chicago, Ill.

18-19—National Society of Professional Engineers, Grand Pacific Hotel and Provident Ins. Bldg., Bismarck, N. Dak.

21-23—American Society of Mechanical Engineers (Power Conference), Hotel Americus, Allentown, Pa.

22—American Society of Safety Engineers, Conrad Hilton Hotel, Chicago, Ill.

22—Association of Consulting Chemists and Chemical Engineers, Belmont Plaza Hotel, New York, N. Y.

28-31—Annual Conference and Trade Fair of Atomic Industry, Plaza Hotel and Coliseum, New York, N. Y.

29-31—American Nuclear Society, Henry Hudson Hotel, New York, N. Y.

November 4-6—American Institute of Electrical Engineers (Machine Tool Conference), Hotel Schroeder, Milwaukee, Wisc.

4-6—American Institute of Mining, Metallurgical and Petroleum Engineers (Institute of Metals Division), Morrison Hotel, Chicago, Ill.

4-6—Society of Automotive Engineers (Transportation Meeting), Statler Hotel, Cleveland, Ohio.

4-8—National Metal Congress and Exposition, International Amphitheatre, Chicago, Ill.

5-6—Society of Automotive Engineers (Diesel Engine Meeting), Statler Hotel, Cleveland, Ohio.

6-8—Industrial Management Society (Time and Motion Study Clinic), Sherman Hotel, Chicago, Ill.

6-8—Society of Automotive Engineers (Fuels and Lubricants Meeting), Statler Hotel, Cleveland, Ohio.

6-8—Society of Rheology, Textile Research Institute, Princeton, N. J.

7-8—Sixth Annual Instrumentation Conference of Louisiana Polytechnic Institute, Louisiana Polytechnic Institute, Ruston, La.

25-26 — Institute of Aeronautical Sciences and Canadian Aeronautical Institute, Montreal, Quebec.

28—Mathematical Association of America (Northeastern Section Meeting), Dartmouth College, Hanover, N. H.

December 1-6—American Society of Mechanical Engineers, Statler Hotel, New York, N. Y.

2-5—American Rocket Society, New York, N. Y.

4-6—American Institute of Mining, Metallurgical and Petroleum Engineers (Electric Furnace Steel Conference).

5-6—Industrial Engineering Conference, Illinois Institute of Technology, Chicago, Ill.

AUTOMATIC VALVES CATALOG — A 12-page condensed catalog featuring their complete line of automatic valves is now available from A. W. Cash Valve Mfg. Corp. The catalog covers main uses, installation tips and construction features, and gives specification tables for each principal series of Cash Acme valves. Cut-away illustrations explain how each valve type is designed.

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_____(57LC-2) *A Study of the Effect of Wear Particles and Adhesive Wear at High-Contact Pressure,* by E. B. Sciulli and G. M. Robinson.

_____(57LC-3) *Chrome Face vs Iron Side Wear—An Analysis of Some Radioactive Piston-Ring Wear Studies,* by R. G. Abowd, Jr.

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ADDITIVE LUBRICANTS

The widespread availability of petroleum lubricants fortified by the inclusion of chemical additives to improve their durability, chemical stability, and lubricating characteristics (by imparting otherwise non-existent properties) presents an interesting set of problems to Management: i.e.,

When to use them.
How to use them.
Why they are used.
How much premium to pay for them.

WHEN TO USE THEM

According to the nature of the additive and the prospective intensity of the service, the objective in the use of an additive type lubricant is to:

1.—Develop a detergent and dispersive ability in an oil, as for example, in heavy duty motor oils.
2.—Impart improved resistance to oxidation, emulsification, and sludge formation, as in turbine and hydraulic oils.
3.—Develop a plating out effect in the resultant oil film which protects metal parts against rusting or corrosion.
4.—Improve the load-carrying (extreme pressure) characteristics in the lubricating film, which is so essential with certain types of gearing.
5.—Depress foam or reduce the tendency of an oil to foam when agitated with air.
6.—Change certain of the physical characteristics for the better. For example, improve the viscosity index (VI) i.e., the relation of viscosity to change in temperature, or reduce the pour point so that the oil will flow at lower temperatures than its base component.

HOW TO USE THEM

No one additive can do all these things; on the other hand there are a considerable number of additives available which will accomplish one or more of each of the objectives when properly compounded into the base lubricant.

This matter of proper compounding is very important. Since temperature, rate of adding and the processing procedure all enter into the picture, normally it is best to use proprietary lubricants in which the additives have been included in the refinery or compounding plant. The amount of any additive which normally is used is relatively small, so to be effective it must be completely and permanently mixed or dispersed in the lubricant. This only can be assured when a suitable mixing or compounding procedure is followed, with equipment suited to the volume and nature of the base lubricant. For this reason so-called re-fortification or adding more additive to a used oil, for example, in industrial operations is not always entirely satisfactory.

Always remember that additives may be expendable, according to the service, the rate of contamination of the lubricant and the type of reconditioning system used with circulating or hydraulic oils. All can reduce the protective effects even to the point of virtual depletion of the additive content.

WHY THEY ARE USED

It is obvious that the function of an additive varies according to the function of the lubricant in which it is to be used. A good comparison can be made between gear oils and heavy-duty motor oils. In a gear oil the primary function of the extreme pressure additive is to improve the pressure-resisting ability of the oil film between the teeth. This requirement became evident around thirty years ago when the hypoid gear became a factor in automotive assembly. Scuffing loads were too extreme for straight mineral oils so the EP additives came into the picture.

It was during that same period that drastic changes were being planned in automotive engine design. Compression ratios were increased resulting in higher engine loads, driving conditions were speeded up with high-speed highway improvements, truck hauling became a definite factor in moving goods and materials. All this set a pattern for more continuous operation, more chance for crankcase oils becoming contaminated via the breather, and condensation due to more widely varying operating temperatures.

Research in the petroleum industry naturally was going on while the automotive industry was making engine changes, for the petroleum chemist was among the first to realize that straight mineral motor oils had to be fortified to meet these changes in engine design and driving conditions. Since then this research has been extended to virtually every other field of machinery operations.

HOW MUCH PREMIUM TO PAY

Management is interested in modern additive-type lubricants not only because of the increase in dependability and the probable beneficial effects on maintenance costs, but also because such lubricants are more expensive than comparable non-additive materials. It therefore becomes a matter of weighing first cost against the obvious benefits of longer machine life and more continuous production.

It also is important when purchasing any additive-type lubricant that the service conditions be thoroughly understood and that they be discussed with the lubrication engineer before final decision is made as to the lubricant and the type of additive it should contain. Performance data is of definite value in making this decision. Sometimes the function of the additive is more important than the function of the oil or grease in which it is contained, even though both must work as a team to produce the ultimate objective — dependable lubrication.

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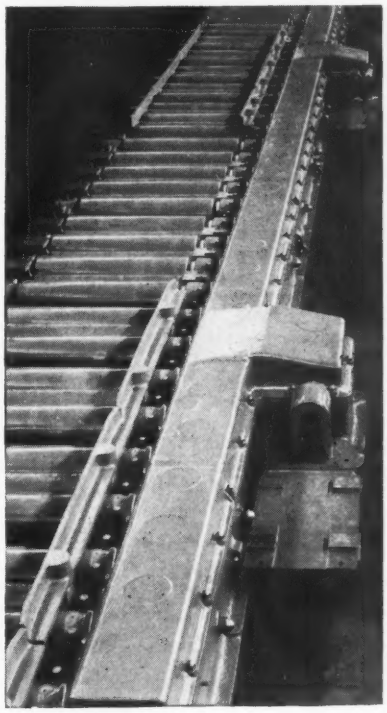
THE BROOKS OIL CO.

Lub-Engineering News

A REPORT ON THE DIFFICULT LUBRICATING PROBLEMS OF INDUSTRY

93% SAVING IN MILL TABLE LUBRICATION COSTS REPORTED BY LEADING STEEL PRODUCER



A leading steel producer recently went through a series of corrective measures to improve lubrication of mill tables. They went from circulating oil system to pressure grease system and finally to automatic spray system.

In the spray system, they used Brooks Klingfast and reported a saving of 93% in lubricant cost. They do not attribute the saving to the change in equipment, as various lubricants were tested. Klingfast offered the greatest reduction in lubricant cost for the application.

Records indicate a 35% decrease in man hours spent on this lubrication job, and 65% less maintenance delays, due to improved lubrication. Klingfast has proved itself against adverse conditions of mill scale, water and high temperatures. Savings in maintenance costs were coupled with increased production.

For full information, write for Engineering Letter 73LE.

NEW COLOR FILM AVAILABLE TO LUBE-ENGINEERING GROUPS

This new 30 minute 16 mm motion picture, in full color, with sound, shows a number of tough lubrication jobs. It pictures and describes the research, manufacturing and quality control methods that enable Brooks lubricants to "stand up" under severest service.

It's available to any supervisory or engineering group interested in lubrication problems. No charge, of course — we're glad to have you see it. Just call or write any of our offices and tell them you want to borrow "The Brooks Oil Story."

CIRCULATING OIL SYSTEMS REQUIRE LUBRICANTS THAT WITHSTAND SEVEREST CONDITIONS

Dust, dirt, water and metallic contamination present extremely difficult problems for circulating oil system lubricants — in steel mills, forging and press shops, cement plants and many other industries. Lubricating compounds must withstand constant contact with contaminants readily dissipate such foreign matter and maintain quality for continued service.

Brooks Leadolene and Klingfast are compounded to meet such severe conditions. These products have served industry for more than a quarter of a century and have broken many records. Companies in the United States and Canada have obtained 5, 10, 15 and 20 years of continued service from these lubricants. For complete facts, see your Brooks representative or write for Engineering Letter 86LE.

THE BROOKS OIL CO. 81st YEAR 1876 1957

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"In 14 months...not a single bearing lubrication failure with lithium-base grease!"

Conveyor-stacker handling moist, sticky material which builds up on the rollers.
Ore unloading conveyor rollers handling 200 tons of ore per hour.
Pinion gear transmitting power from 600 h.p. motor to a ball mill.
Pan Conveyor handling hot clinker (1600°F), roller bearings in dusty, moist atmosphere.
Leach tanks handling hot slurry, agitators driven by Falk gear reducing units.
V.A. Wemco classifier, part of wet grinding system, lower bearing submerged in hot sludge.

THE PROOF IS IN THE PERFORMANCE...

lithium-base grease does the job...

and does it better!

Here's a report of our own experience with lithium-base grease under extreme industrial service conditions. Approximately 95% of the grease used in the plant of AMERICAN LITHIUM CHEMICALS, Inc., our subsidiary at San Antonio, Texas, is lithium-base, one-type grease. In fourteen months operation we have not been able to trace a single cause for bearing failure to the lubricant used. The on-the-spot photos above give graphic evidence of the rugged bearing service requirements in this plant where lithium ores are processed into high-grade lithium hydroxide, itself an important ingredient in lithium-base grease. Performance like this is why grease chemists, manufacturers, marketers and users all attest to the superiority of lithium-base... the *one* grease in place of *many* for efficient and economical operation.

Want to know more about TRONA lithium hydroxide monohydrate? Send for our technical bulletin on this important chemical ingredient in lithium-base greases.

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FUNGI AND BACTERIA STOPPED DEAD WITH CSC TRIS-NITRO

Ideal in Cutting Oils, Oil Well Flooding, Pipe Lines and Drilling Muds

Tris-Nitro—Tris (hydroxymethyl) nitromethane—checks unwanted microbiological growth in aqueous systems. Long known as a hardening agent for proteins under slightly alkaline conditions, Tris-Nitro is a powerful inhibitor of microorganisms as well.

SLOW RELEASE OF FORMALDEHYDE APPARENT SECRET OF SUCCESS

The inhibition mechanism of Tris-Nitro is apparently due to the gradual release of formaldehyde which offers sustained protection for a prolonged period. Recent experiments show that formaldehyde is also slowly released at high humidities and high ambient temperatures in the presence of a trace of alkaline material. Tris-Nitro may also be useful in its dry form to protect packaged goods from mold attack during shipment and storage.

TRIS NITRO'S PROPERTIES ARE WORTH LOOKING OVER

Formula	$(CH_3OH)_3CNO_2$
Molecular Weight	151.12
Melting Point, °C	165-170 d
pH of 0.1M Aqueous Solution	5.6
Solubility in Water, g/100 ml at 20°C	220

CUTTING OIL SYSTEM FULLY PROTECTED WITH JUST 0.1% TRIS-NITRO!

More than 200 compounds were tested in open cutting oil systems. Only 0.1% Tris-Nitro kept system free of bacterial contamination for over 60 days — longer than any other compound tested!

GET SAMPLE AND FURTHER INFORMATION. TO HAVE A REPRESENTATIVE DISCUSS APPLICATIONS WITH YOU, WRITE CSC TODAY.

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Give Your Speed Reducers a treat.

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ASLE JEWELRY

The new ASLE jewelry is available in the form of tie clasps, lapel pins, or cuff links at $3.50, $1.50, and $4.50 each, respectively, from the National Office. Many of the Sections are using the jewelry in their membership campaigns. Details are available through the National Office.

"CLICK" lubrication starts when your machines start!

ALEMITE OIL-MIST

AUTOMATIC LUBRICATION

provides constant, foolproof uniform lubrication— to protect *any* moving surface!

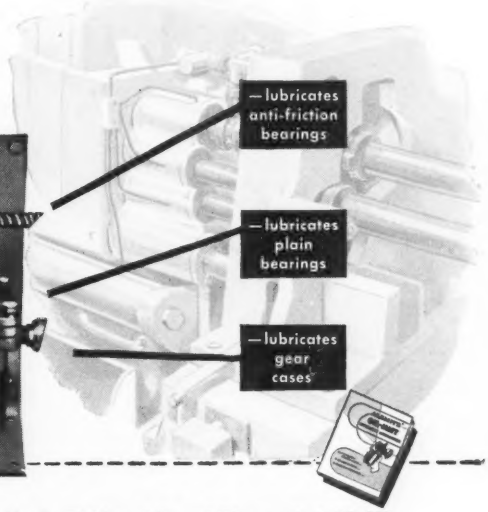
Alemite Oil-Mist lubrication can be easily designed into any new or installed machine. This simple, continuous, completely automatic system eliminates human error—multiplies bearing life—reduces product spoilage—boosts machine output! Operates on compressed air . . . starts and stops when machine switch is turned on and off. Airborne lubricant is conveyed through tubing to bearings. Mail coupon below for full details about Alemite Oil-Mist. Now in use on modern, high-speed machines.

Lubricates any bearing on any machine with one of three types of fittings:

Mist fittings for roller, ball, needle—or any anti-friction type of bearings.

Spray fittings for open and enclosed gears and chains.

Condensing fittings for plain bearings, slides, ways, vees, cams, and rollers.



8 Advantages of the Alemite Oil-Mist System

1. Continuous lubrication. Deposits fresh, clean film of oil on all surfaces of all bearings.

2. Fully automatic. Starts and stops with operation of machine switch.

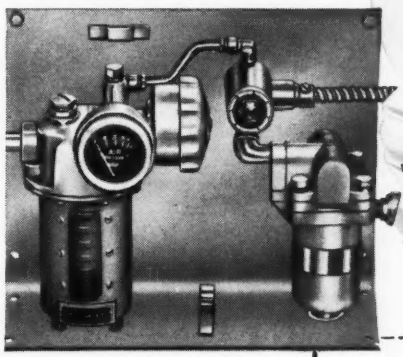
3. No guesswork. Bearings can't be overlooked, or over-lubricated!

4. Reduction of bearing temperatures. Acts as bearing coolant. Reduces bearing temperatures as much as 20°F.

5. Fewer types of oil. Reduces number of oils that must be stocked, handled and applied.

6. Elimination of downtime. All bearings are constantly lubricated while machines continue to operate.

7. Extension of bearing life. Life of grinding machine bearings have been extended from 400 to 7,000 hours!



8. As high as 90% less oil consumption. Usually consumes about 1/10th amount used by any other oiling method.

Mail coupon for Oil-Mist demonstration and information

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Hodson's No. 464 Extrusion Compound for aluminum definitely increases production, resulting in better finish, increased die life. No occupational hazard is afforded in using our aqueous colloidal graphite compound.

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